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THE INSTITUTION OVERSEA

IT MAY COME AS A SURPRISE TO SOME MEMBERS to learn that there are nearly 3 500 Corporate Members of The Institution resident oversea. It is the constant aim of the Council to strengthen the ties linking The Institution at home and abroad, for it is realized that the oversea member, unable to attend meetings and discussions at The Institution's headquarters in London, often has greater need of meeting his fellow engineers and discussing problems of mutual interest than the engineer at home, who in the course of his daily work and travels has many such opportunities, both in and out of The Institution.

To meet this need The Institution has, in the past, created Oversea Branches, has set up Oversea Committees or appointed Oversea Representatives of the Council, according to the numerical strength and location of members and to other circumstances. In these matters the three senior Institutions of Civil, of Mechanical and of Electrical Engineers not infrequently join forces in oversea work by the establishment of Joint Oversea Groups in such places as the Argentine, Hong Kong, Iraq, Malaya, and West Africa. The standards, aims and objects of the British Engineering Institutions serve also as the pattern for smaller organizations in many oversea territories where engineering is playing a comparatively small but ever growing part in the development of national resources. One such organization is the East African Association of Engineers. This Association, membership of which is open to Corporate Members of the three home Institutions, and to others who meet the Association's own requirements for membership, covers the territories of Kenya, Tanganyika and Uganda. Its activities resemble those of the home Institutions, and though its membership is, at the moment, relatively small, there seems little doubt that the developments of East Africa will see the Association growing in strength and numbers. If in the fullness of time the Association were to be invited to accept membership of the Conference of Commonwealth Engineering Institutions, this would be a natural outcome of its development.

It is a source of pleasure to the Councils of the home Institutions to observe the coming to full stature of autonomous societies of engineers in oversea territories of the Commonwealth, for this is in fulfilment of the policy endorsed by all the participating Institutions of the Commonwealth Conference, that the first duty of an engineer is to support his own national engineering Institution. He can of course seek additional membership if he feels the need for closer attention to his own specialized branch of engineering than his local engineering society is able to provide. It was in furtherance of this policy that the Commonwealth Engineering Societies agreed that none would carry out activities in the territories of other members unless at the request of, and by agreement with, the national society of the territory concerned.

These arrangements have been quoted because they appear to be symptomatic of the attitude of mind of the professional engineer oversea in keeping contact with his profession and with the progress of science and engineering which it exists to foster. He clearly feels the need of some local organization which will help him to extend his engineering and scientific knowledge and to keep him up to date. In many countries also—particularly in the almost ubiquitous multi-racial territories which now comprise the Commonwealth—there is a widely felt need for some separate protective organization to uphold and to improve the status of the professional engineer.

While the objects and purposes of The Institution, as set out in its Charter, do not include a watch on the status and personal interests of its members, The Institution has developed a widespread organization for bringing knowledge of advances in the science and practice of engineering to its members oversea. There are Branches in India, Ceylon and Ireland; Oversea Committees in places as widely separated as Australia, India, Singapore and New Zealand; and Oversea Representatives of the Council at thirty different places ranging from the United States to Hong Kong and from Switzerland to Brazil. The Council are examining the usefulness of establishing additional organizations in one or two other parts of the world; if there is need for yet others, they would be glad to hear of it.

An Electrical Engineering Review

FERROELECTRIC MATERIALS

Since the end of the 1939–45 War there has been a considerable development of a new group of dielectric materials called 'ferroelectrics'. To-day, these materials are available to the electrical engineer and he would be wise to acquaint himself with their basic properties to be able to assess their potentialities in his particular activity. It is the purpose of this review to present this information to him and to clarify some of the apparent complexity of the properties of ferroelectric materials by explaining the physical principles involved. Mr. Popper is at present carrying out research into new dielectrics at the laboratories of the British Ceramic Research Association.

By P. POPPER, B.SC., MEMBER

STRUCTURE AND PROPERTIES OF FERROELECTRICS

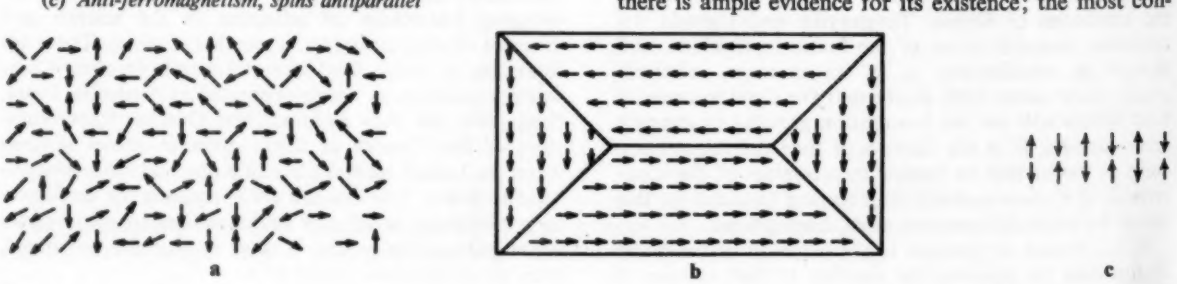
THE name *ferroelectric materials* or, in short, *ferroelectrics*, might give the impression that these materials contain appreciable amounts of iron. In fact, no ferroelectric material known to-day contains iron. The name 'ferroelectricity' has been chosen to indicate the close resemblance of the mechanism of electrical polarization to that of the magnetization of ferromagnetic materials. As electrical engineers are familiar with the properties of ferromagnetic materials, which they have used since the earliest days of electrical engineering, it will be most suitable to introduce the fundamentals of ferroelectricity by way of an analogy with ferromagnetism.

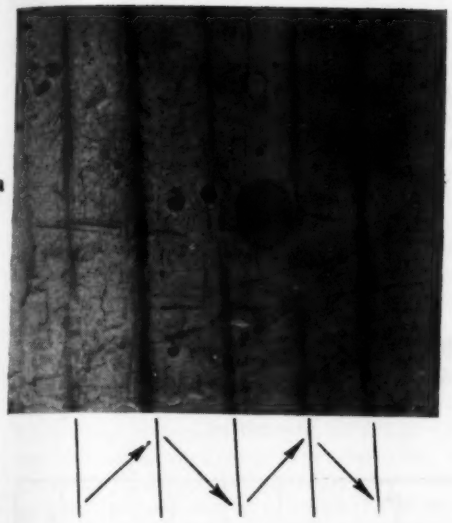
Ferromagnetism

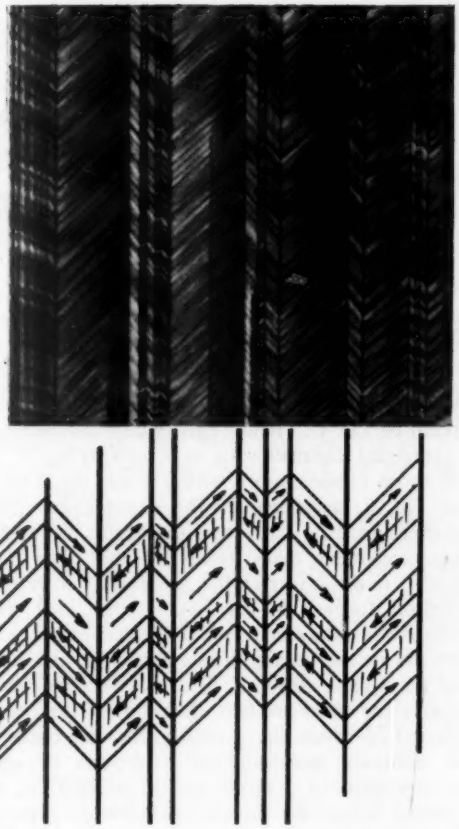
There is now indisputable evidence that an electron—besides being the carrier of the smallest electric charge—possesses a magnetic moment, like a compass needle. The magnetic moment is referred to as its 'spin'; this suggests a picture of the electron as an electrically-charged spinning sphere, which, being equivalent to a circulating current, produces a magnetic moment. In a gas or a paramagnetic solid, interaction between the magnetic moments is weak and the thermal energy maintains the directions of the magnetic moments in a state of statistical randomness. This is illustrated in Fig. 1(*a*), where the magnetic moments of the spins are represented by small arrows. In ferromagnetic materials, on the other hand, the interaction of the electron spins is much greater and if their temperature is decreased, a state is reached where the thermal energy is insufficient to overcome the forces of interaction and all spins align parallel [Fig. 1(*b*)]. The temperature at which this occurs is called the Curie point, and above it any ferromagnetic substance is paramagnetic, or in common language, 'loses its magnetism'.

From what has been said so far, it would appear that every ferromagnetic material below a critical temperature would always be spontaneously magnetized, or behave just as a permanent magnet. This conclusion is obviously contrary to the experience that ferromagnetic materials can be brought into an apparently demagnetized state by suitable magnetic or heat treatment. The apparent discrepancy was obviated by Weiss's ingenious suggestion that a ferromagnetic body consists of a great number of small regions called domains. The spins in each domain are aligned in parallel but the direction of spontaneous magnetization varies from one domain to another. The application of a magnetizing field causes an increase in the number of spins aligned in the direction of the applied field. This increase can come about either by rotation of the spontaneous magnetization of whole domains or by the growth of favourably oriented domains at the expense of others. In this way it is possible to explain the characteristic ferromagnetic properties exhibited in the hysteresis loop, i.e. saturation, remanence and coercive force. The domain structure of ferromagnetic materials was, at its inception, a pure hypothesis. To-day, however, there is ample evidence for its existence; the most con-

1 (*a*) *Paramagnetism, spins at random*
(*b*) *Ferromagnetism, spins parallel within domains*
(*c*) *Anti-ferromagnetism, spins antiparallel*







2 (*a*) (*left*) *Ferromagnetic domains of single crystal of iron*
(*b*) (*right*) *Ferroelectric domains of barium titanate*

2a **2b**

vincing one is undoubtedly the Bitter powder patterns shown in Fig. 2(*a*), which is a photomicrograph of the polished surface of a single crystal of iron onto which finely divided iron-oxide powder has been settled from a colloidal suspension.

Many materials like manganese oxide, ferrous oxide, ferrous sulphide, chromic oxide, etc., previously considered not to be ferromagnetic, have in recent years been classified as 'anti-ferromagnetic'. Their spin alignment, which is antiparallel, is shown in Fig. 1(*c*). As in ferromagnetic materials, the interaction resulting in the antiparallel arrangement is opposed by thermal agitation and is overcome at a critical temperature called the 'anti-ferromagnetic Curie point'. This transition is, however, not accompanied by striking changes in the magnetic properties, and for that reason has escaped notice until recently.

Table 1. Ferroelectrics and their Curie points

Chemical formula of ferroelectric	Curie point °C	Chemical formula of ferroelectric	Curie point °C
$BaTiO_3$	125	$Li(NH_4)C_4H_4O_6.H_2O$	
$PbTiO_3$	490	WO_3	− 50
$KNbO_3$	434	KH_2PO_4	−150
$LiNbO_3$		RbH_2PO_4	−127
$KTaO_3$	−260	KH_2AsO_4	−177
$LiTaO_3$		RbH_2AsO_4	−163
$Cd_2Nb_2O_7$	− 85	CsH_2AsO_4	−130
$KNaC_4H_4O_6.4H_2O$ (Rochelle salt)	−18 to +24	$CN_3H_6.Al(SO_4)_2.6H_2O$ (GASH, guanidine aluminium sulphate hexahydrate)	200

Table 2. Anti-ferroelectrics

$PbZrO_3$ (Curie point 230° C)	$ND_4D_2PO_4$	$(NH_4)_2H_3IO_6$
$NaNbO_3$	$NH_2H_2AsO_4$	$Ag_2H_3IO_6$
$NH_4H_2PO_4$ (Curie point −125°C)	$ND_4D_2AsO_4$	WO_3

Ferroelectricity

By analogy with ferromagnetism, ferroelectricity can be described as a spontaneous polarization. Polarization in dielectric materials can be due to:

(*a*) Displacement of the centre of gravity of the negative charge of the electrons relative to the positive nucleus.

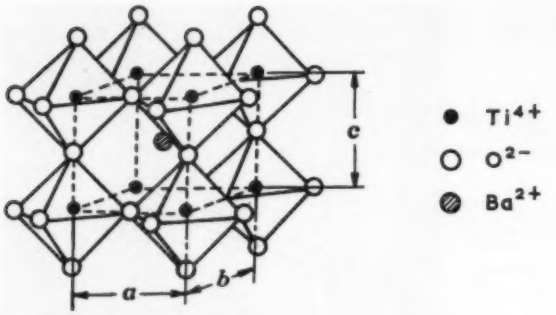
(*b*) Displacement of the negative and positive ions relative to one another (e.g. Na^+ and Cl^- in NaCl).

(*c*) Alignment of permanent electric dipoles.

Ferroelectricity will occur if any of these mechanisms —either singly or in combination—happen spontaneously, i.e. without the application of an external electric field. A number of materials have been found to be ferroelectric (Table 1), but, on the whole, ferroelectricity is rather a rare phenomenon, particularly at room temperature and above. Anti-ferroelectricity, the analogue of anti-ferromagnetism, also exists in a number of compounds (Table 2) but has as yet not found any practical applications.

Barium titanate, $BaTiO_3$, is, from a practical point of view, the most important ferroelectric and is used as an example to demonstrate how a spontaneous polarization can arise.

The structure of barium titanate is shown in Fig. 3 (p. 452). The unit cell is shown as a cube ($a = b = c = a_0$),



3 *Structure of barium titanate*

which represents accurately the structure above the Curie point of 125° C. Below this critical temperature a slight tetragonal distortion ($a_t = b_t = 0{\cdot}997a_0$, $c_t = 1{\cdot}007a_0$ at room temperature), which is too small to be shown in Fig. 3, accompanies the spontaneous polarization. Simultaneously with the distortion, a slight atomic rearrangement takes place, so that the titanium ion (Ti^{4+}) is no longer in the geometric centre of the octahedron formed by the six oxygen ions (O^{2-}). This relative displacement of the electrically charged ions results in the polarization referred to above. Since any of the 3 cube edges (*a*, *b*, *c*) can become the tetragonal *c*-axis and there are two directions of the *c*-axis (up and down) in which the displacement can occur, there are 6 mutually perpendicular directions of spontaneous polarization in a single crystal of $BaTiO_3$, when it is cooled below the critical temperature. The regions of uniform spontaneous polarization are the ferroelectric domains. These can readily be distinguished under the microscope by using polarized light, since the tetragonal crystal is optically anisotropic. Domains with parallel *c*-axis but opposite polarity can be distinguished by an etching treatment.

A photomicrograph of ferroelectric domains is shown in Fig. 2(*b*) (p. 451). The change in relative size of such domains as a voltage is applied to the crystal has also been observed under the microscope.

When one considers the electrical properties of ferroelectrics in general, it is important to keep the following points in mind.

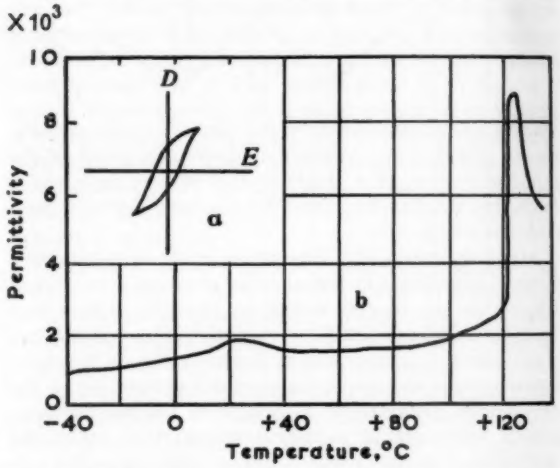
(i) Ferroelectrics exhibit hysteresis between applied voltage and resulting charge. In this respect there is a close analogy between the *B*/*H* loop of a ferromagnetic material and the *Q*/*V* or *D*/*E* loop of ferroelectrics (charge *Q*, voltage *V*, electric displacement *D*, and electric force *E*).

(ii) The permeability of paramagnetic materials, which include ferromagnetic ones above the Curie point, is only slightly greater than 1 (e.g., the permeability of aluminium is 1·002). The permittivity, or dielectric constant, of 'paraelectrics', i.e. the normal non-ferroelectric dielectrics and ferroelectrics above the Curie temperature, can be many times greater than 1 (e.g. the permittivity of aluminium oxide is 9, of titanium dioxide is 110, of strontium titanate is 200).

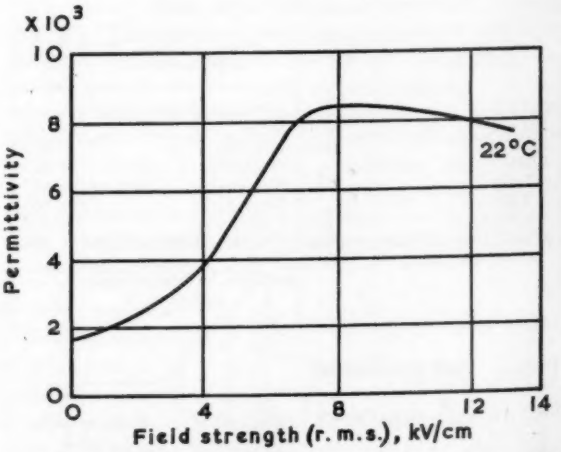
In this last respect ferroelectrics differ from ferromagnetic materials. In the latter the Curie point is associated with a very sharp drop of the permeability to approximately 1, whilst ferroelectrics exhibit a peak of the permittivity/temperature curve at the Curie point. A very high permittivity is often associated with ferroelectric materials and for that reason they are often called high-permittivity dielectrics or 'high-K' dielectrics. High permittivity, however, is not an essential property of a ferroelectric and this is demonstrated by guanidine-aluminium–sulphate ($\epsilon_{0\parallel} = 15$, $\epsilon_{0\perp} = 5$). Hysteresis and the existence of spontaneous polarization are much safer criteria by which the presence of ferroelectricity may be judged.

Electrical Properties of Barium Titanate

A hysteresis loop of barium titanate is shown in



4 (*a*) *D*/*E hysteresis loop*
(*b*) *Variation of initial permittivity of barium titanate with temperature at 1 Mc/s*



5 *Dependence of permittivity of barium titanate upon field strength at 50 c/s*

Fig. 4(*a*). Hysteresis—as is well known from the application of ferromagnetic materials—necessitates more precise definition of the parameters which describe the properties of the material. Thus it is no longer sufficient to ask what are the permittivity and dielectric loss of barium titanate at room temperature. It is necessary to specify the frequency and field strength resulting from the alternating voltage applied to the material (Fig. 5). In addition one must know whether a direct voltage is applied simultaneously. The permittivity depends on this just as much as the inductance of an iron-cored choke varies with the magnitude of a direct current flowing through its windings.

Fig. 4(*b*) shows the temperature dependence of the initial permittivity ϵ_0 of barium titanate. This decreases only gradually as the temperature rises above 125° C, the Curie point of barium titanate, very high values of permittivity being obtainable at temperatures considerably above the Curie point. Below this point there is a quite wide temperature interval in which the initial permittivity is about 1 600. The designation 'initial permittivity', necessary on account of the hysteresis phenomena, implies that the measurement was made using very small alternating voltages and the absence of any direct polarizing voltage before and during the measurement, which would have decreased the effective permittivity.

The above-mentioned saturation phenomena are a consequence of the domain structure of ferroelectrics. Also connected with it are slow changes of permittivity with time. This 'ageing' is particularly noticeable in ferroelectrics which have been depolarized by heating above the Curie point for a short time. The rate of decrease in permittivity which occurs after the sample has been cooled to room temperature is at first high, but soon becomes negligible and does not cause any difficulties except in applications requiring great stability.

Electromechanical Properties of Barium Titanate

When barium titanate becomes polarized, more domains are oriented with their *c*-axis more nearly parallel to the direction of the applied field than corresponds to the random orientation of the unpolarized substance. It follows from the geometry of the tetragonal unit cell ($c_t > a_0 > a_t$) that polarization will be accompanied by an expansion in the direction of the applied field and a contraction perpendicular to it.

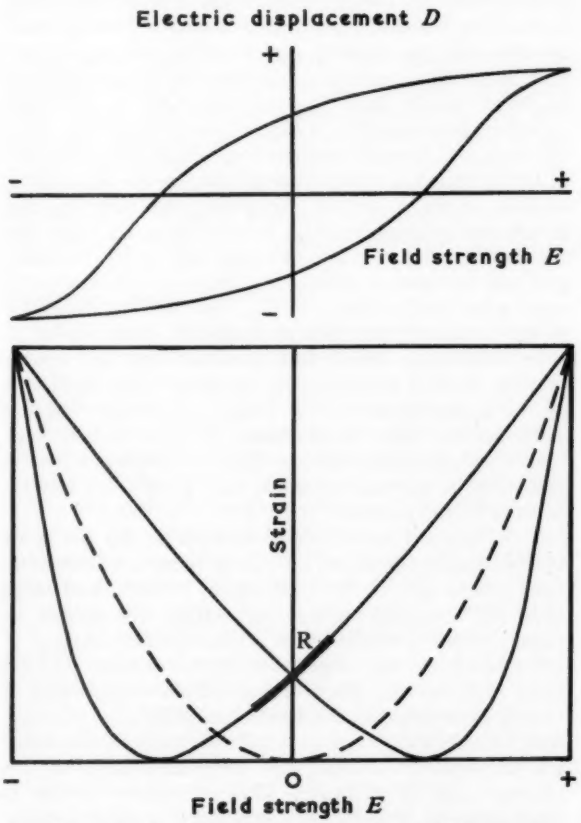
The dimensional changes caused by the polarization field are clearly independent of its polarity. The strain/electric-field curve resembles a parabola, which is shown as the dotted portion of the curve in Fig. 6. This dotted line corresponds to polarization from the depolarized state. It is the 'virgin' strain curve. The fully drawn curve of a complete cycle is strongly reminiscent of the 'butterfly-loop' of reversible magnetostriction. The thickened portion of the butterfly loop near the remanence point R indicates the changes in length which will occur when a small alternating voltage is applied to a material in the remanent state. The response to such a signal is now linear. Similarly a mechanical stress produces a surface charge whose polarity depends on whether the material is stretched or compressed. These phenomena correspond to the piezo-electric effect and its inverse. Polarized barium titanate behaves therefore in the same way as a piezo-electric substance.

Manufacture of Barium Titanate

It has already been pointed out that barium titanate is one of the few materials whose ferroelectric range lies at normal operating temperatures. It can be produced from materials which are readily available and cheap.

Barium titanate, $BaTiO_3$, is formed by solid reaction when barium carbonate, $BaCO_3$, and titanium dioxide, TiO_2, are intimately mixed and heated to about 1 250° C. The product so formed is broken up into fine particles, from which the required shapes are then produced by the usual ceramic techniques of pressing, extrusion, casting into a plaster mould, etc. After this, the articles are sintered to dense impervious bodies by a further high-temperature firing.

Electrodes can be formed by brushing, spraying or silk-screen printing of suspensions of silver (either with or without silver oxide) in organic liquids on to the ceramic surface. After heating to about 800° C, a well-adhering, highly conducting layer of silver is formed in



6 *Variation of strain of barium titanate with field strength*

intimate contact with the ceramic. Wire or metal strips may be soldered to the silvered surface.

Pure barium titanate is rarely used to-day. Certain additions of other oxides, depending on the particular application, are made to obtain the desired properties.

APPLICATIONS OF FERROELECTRICS

It takes some time for the full potentialities of a new material to be realized and even longer to put them into production. This stage has hardly been reached yet with the ferroelectric materials. However, in many applications they offer such obvious advantages either economically or in performance that it can be said that ferroelectrics have come to stay. Other applications have still to be worked out or await the development of materials with specific properties.

The basic properties of ferroelectrics suggest three groups of applications which make use of:

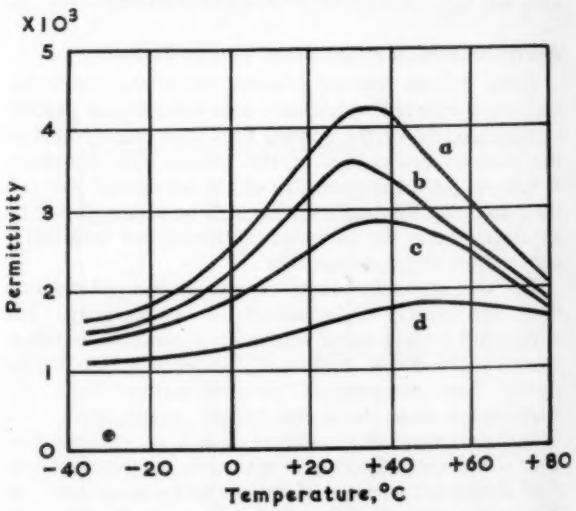
(i) The high permittivity.
(ii) The non-linearity of the hysteresis loop.
(iii) Electro-mechanical properties.

Ceramic Capacitors

In the discussion of the electrical properties it has been pointed out that barium titanate has a very high initial permittivity but that this property is not very stable since it varies with temperature, direct and alternating voltage and time. Such a material cannot be used in tuned circuits or filters where high frequency-stability is essential. However, large numbers of capacitors are used as by-pass, blocking and smoothing capacitors whose main function is to present a low-impedance path to an alternating current above a certain frequency. As long as the impedance remains below a certain designed value for the working life of the equipment and under the temperature fluctuation which it is likely to experience, the apparatus will function correctly. Ferroelectric materials of the titanate group with permittivities of the order of several thousand satisfy this condition and are consequently used in considerable quantities. The small size of the components has the further advantage that the self-inductance due to electrodes and leads can be kept low. A large capacitor at 100 Mc/s may easily be equivalent to an inductor rather than a capacitor because of the lead inductance.

The shape of capacitors is determined by the most economic manufacturing processes; tubes are formed by extrusion, discs by dry pressing of powder, and large capacitors for high-voltage application are shaped by hand on the 'potter's wheel'. The electric strength of the ceramic bodies is such that for low-voltage applications (<500 volts) the thickness of the components is largely determined by mechanical consideration. Capacitors whose capacitance in picofarads exceeds five times the permittivity become very large and thin and are consequently very fragile. The capacitance which is obtainable in low-voltage capacitors is thus limited. Attempts to make large-value low-voltage capacitors by stacking a number of plates, as is used in mica capacitors, have so far proved uneconomical. Another application well suited to ceramic capacitors is in high-voltage smoothing capacitors. Little use has as yet been made in high-voltage capacitors at power frequencies, where the power storage of the dielectric and the cost of production of a stack of a number of ceramic plates compare unfavourably with the power storage and cost of an oil-impregnated paper capacitor.

By mixing ferroelectric barium titanate with non-ferroelectric strontium titanate it is possible to shift the Curie temperature, and with it the peak permittivity, towards lower temperatures, and therefore to obtain permittivities greater than that of pure barium titanate at room temperature. However, the permittivity/temperature curve of barium–strontium titanate exhibits a very pronounced peak, and as the minimum permittivity under working conditions is the important criterion, the peak values are unimportant. Capacitor manufacturers have, therefore, looked for materials with a broad peak rather than for a sharp peak with extremely high permittivity. Fig. 7 shows a typical example of a high-permittivity dielectric used in high-value capacitors. It also shows the decrease of the initial permittivity when a large direct voltage is applied simultaneously with the small alternating voltage. It is to be noted that the decrease is most marked at the peak-permittivity temperature. The effect of a direct voltage, which is nearly always present under the actual working conditions of the capacitor, is therefore somewhat to flatten the peak. The power factor of this type of material—a quantity to which undue significance should not be attached—is about 1%. This type of material is obtained by a judicious mixture of various alkali-earth titanates, zirconates, etc. The methods by which the particular results are achieved

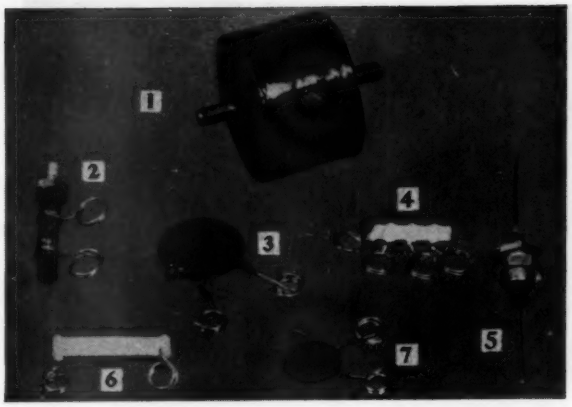


7 *Variation of permittivity of high-permittivity material with temperature and applied direct voltage*
(*a*) $V = 0$.
(*b*) $V = 1{\cdot}0$ kV/mm.
(*c*) $V = 1{\cdot}4$ kV/mm.
(*d*) $V = 2{\cdot}8$ kV/mm.

are more-or-less empirical and resemble the development of an alloy with particular properties.

A difficulty which has occurred in the past was the deterioration of the insulation resistance of a capacitor during the working life. For normal working conditions this trouble has been overcome but it imposes a temperature limit on capacitors working under very high voltage stress.

So far, high-permittivity ceramic capacitors have been applied with greatest advantage at low voltages in the capacitance range of 500–10 000 pF. Large numbers are used in the modern television receiver as by-pass capacitors. Fig. 8 shows a range of capacitors of various capacitance and voltage rating and different types of construction.



8 *Ceramic capacitors*

1. 500 pF, 16 kV d.c. Diameter = 3 cm. Length = 2 cm.
2. 2 × 2 200 pF for chassis mounting.
3. 10 000 pF double-disc. Diameter = 1·7 cm.
4. 3 × 500 pF tubular.
5. 4 700 pF feed-through capacitor.
6. 10 000 pF tubular. Length = 2·2 cm.
7. 2 000 pF disc.

Applications Making Use of Non-linearity and Hysteresis

The similarity between dielectric- and magnetic-hysteresis loops suggests a number of applications. These are now under investigation in many laboratories and some may eventually become important applications of ferroelectric materials.

Frequency Modulation. The dependence of the reversible permittivity on a polarizing voltage permits the changing of the resonance frequency of a tuned circuit by means of a direct voltage, or modulating of a carrier frequency by a low-frequency voltage. Two main difficulties have been encountered:

(i) If small modulating voltages are to be used the ceramic must be very thin.

(ii) The maximum sensitivity to a modulating voltage occurs near the peak permittivity point, where the differential permittivity is very strongly temperature dependent and likely to fluctuate with time.

Information Storage. One of the most interesting potential applications of the square-shaped hysteresis loop of single crystals is their use as an information-storage device for electronic computers. In principle, this works in the same way as magnetic storage, which also relies on a square-shaped hysteresis loop. The information to be stored on any one unit consists of two alternatives: '0' and '1'. These are fed into the storage device by pulses of opposite polarity, thereby bringing the ferromagnetic or ferroelectric into one of the two possible states of remanence [Fig. 9(*a*), p. 456]. This information can be stored until required, when it can be 'read out' by noting the response to a 'reading pulse'. The basic storage circuit is shown in Fig. 9(*b*). Oscillograms of the input and output waveform are shown in Fig. 9(*c*). Pulse A represents the storage of a '1' pulse, C of a '0' [Fig. 9(*d*)]; pulses B and D are reading pulses. The large output pulse 'b' corresponds to '1' and is produced by the reversal of the polarization.

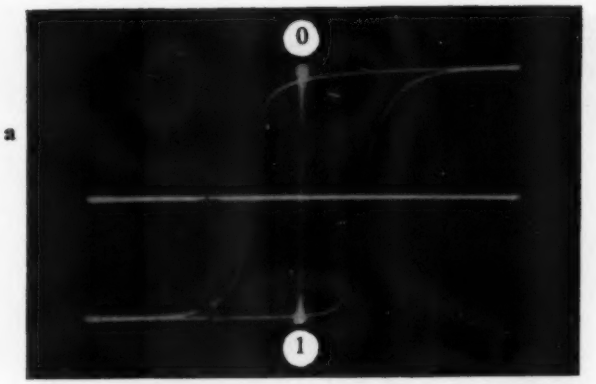
One advantage of the ferroelectric device over a magnetic one using ferrites is that it consumes less current and is thus more suited for valve or transistor circuits. It has also been shown that a number of storage elements can be used on a single crystal plate without interference from one to another. This permits the construction of a compact unit.

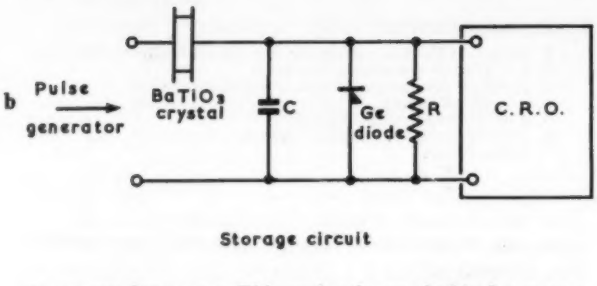
Dielectric Amplifier. This is the analogue of the magnetic amplifier, which requires magnetic materials with narrow rectangular hysteresis loops. Accordingly, the dielectric amplifier works most efficiently if single crystals are used. With crystals 0·002 inch thick and electrodes 0·004 inch or less in width, and a carrier frequency of 200 kc/s, a power amplification of 12 dB has been achieved over a frequency band of 7 000 c/s.

Electro-mechanical Transducers

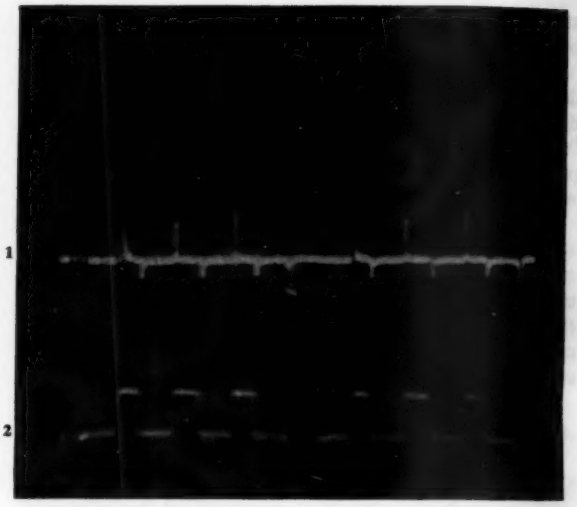
It has been shown that polarized barium titanate possesses piezo-electric properties and, in principle, one would therefore expect that it can replace quartz, Rochelle salt or any of the other piezo-electric materials in use to-day. Before discussing the relative merits of different materials in these applications, it should be pointed out that barium–titanate ceramics, prior to their use in electro-mechanical transducers, i.e. convertors of electrical into mechanical energy and vice versa, are subjected to a special heat treatment. The treatment consists of heating the material above the Curie point. A voltage of a few thousand volts per millimetre thickness is then applied to the electrodes, and, whilst subjected to this voltage, the ceramic specimen is cooled through the Curie point. In this way a great number of domains are formed whose *c*-axis is in the direction of the applied field. This domain structure remains 'frozen in' at room temperature even when the electric field is removed, and gives a very stable polarization.

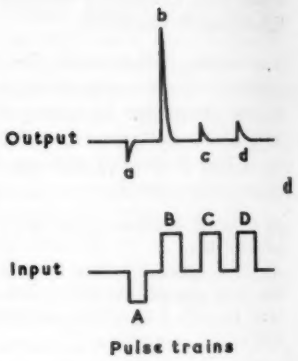
The greatest disadvantage of barium titanate compared with quartz is its low stability of mechanical





Storage circuit





Pulse trains

9 (*a*) *Hysteresis loop of single crystal*
(*b*) *Information-storage circuit*
(*c*) *Oscillograms of input and output waveforms*
1. Output. 2. Input.
(*d*) *Drawing of input and output waveforms*

resonance frequency. This makes it unsuitable for use as a resonator for frequency stabilization. Some improvements have been obtained by the addition of lead and calcium titanate and the application of special ageing procedures. Its use in filters and delay lines can now be considered.

One of the great advantages of a ceramic transducer for the generation of ultrasonic waves is that it can be fabricated in a large variety of shapes. These are required when it is desired to concentrate the energy to produce very intense ultrasonic oscillations or to radiate it in certain directions (e.g. underwater signalling). The concave and tubular transducers (see Fig. 10) are examples of this. Barium titanate can be used for transducers in large power applications; the cost of similar quartz transducers would be prohibitive. Barium–titanate transducers have also been used with advantage for the testing of castings by the 'echo method'. If the directions of the d.c. polarizing and a.c. energizing fields are perpendicular to each other, torsional oscillations can be produced.

The conversion of mechanical into electrical energy also has useful applications. The pressure of 1g/cm^2 on a barium–titanate disc of 1 cm^2 area and 0·5 cm thickness produces an output of about 2·5 mV. A device making use of this is the small accelerometer shown in Fig. 10.

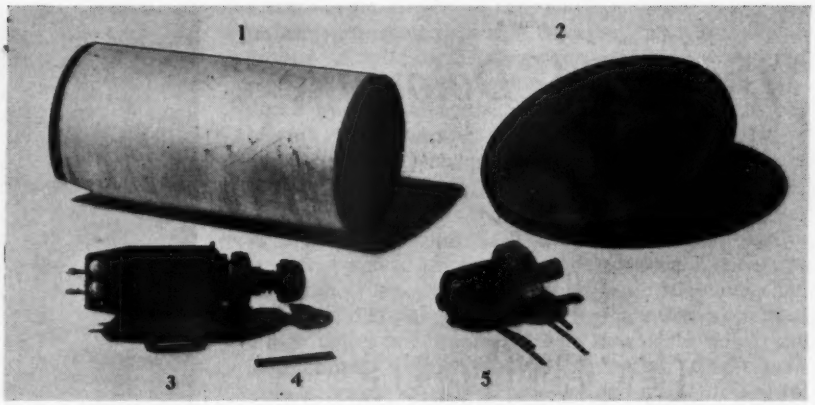
Elements sensitive to bending can be made by soldering together two thin rectangular plates. If the top and bottom plate are polarized in opposite directions the output due to the stresses with opposite signs in the two plates will not cancel but add. Such composite bender elements are used in gramophone pick-ups, for measurements of surface roughness, and of the viscosity of liquids and ceramic slips. Ceramic transducers based on barium titanate work satisfactorily up to 70° C and are not affected by moisture. Thus they are not subject to the limitations of Rochelle salt. Some of the more recently discovered ferroelectrics should operate up to even higher temperatures on account of their higher Curie point.

Future Outlook

Because of the great possibilities of the application of single crystals in 'information storage' or 'memory' devices, work in research laboratories is mainly concentrated on the study of single crystals of ferroelectrics. A much greater understanding of the process of polarization has been gained by observation of the domain structure in single crystals. The knowledge gained will no doubt further the understanding of the much more complex problem of the polycrystalline ceramic materials. In these, the importance of the grain size is only now being realized and better reproducibility and improved properties will be obtained in the future.

10 *Electromechanical transducers*

1. Tubular transducer: length = 3 in.; outer diameter = 1½ in.; inner diameter = 1¼ in. Length resonance at approx. 33 kc/s; thickness resonance at approx. 800 kc/s.
2. Disc transducer: diameter = 2½ in.; thickness = ¼ in. Thickness resonance at approx. 800 kc/s.
3. Gramophone pick-up using barium-titanate bender.
4. Barium-titanate bender made of two plates 17 × 2 × 0·3 mm.
5. Barium-titanate accelerometer.



Using once more the analogy between ferroelectrics and ferromagnetics, one may say that the present state of knowledge of ferroelectrics is not unlike that existing 30 years ago for ferromagnetic materials, when a more intense study of the properties of single ferromagnetic crystals began. As a consequence of this, we have to-day a variety of magnetic materials with different properties, from which one can choose the one most suitable for a particular application. With the more intensive research of to-day and by using the knowledge gained on ferromagnetic materials, the equivalent result should be reached sooner.

Besides this study of the properties of the known materials—in particular of barium titanate—the search for new ferroelectrics continues and might result in the discovery of a material with unexpected properties.

Acknowledgments

The author wishes to acknowledge gratefully the supply of photographs by: Professor L. F. Bates and Dr. D. H. Martin [Fig. 2(*a*)]; Dr. W. T. Merz [Fig. 2(*b*)]; and Mr. C. F. Oxbrow (Fig. 9).

CORRESPONDENCE

WHAT IS PERMEABILITY?

From LAURENCE H. A. CARR, M.SC.TECH., MEMBER

Professor E. G. Cullwick's proposals (following Professor G. W. Carter), which appeared in the July issue, fall into two categories: (*a*) symbols and (*b*) titles, and these require to be considered separately.

(*a*) After about fifty years' work, and many difficulties, the British Standard symbols, as published in B.S. 1991: Part 1: 1954, now agree *exactly* (except for a very occasional allowable alternative) with the symbols agreed internationally by the International Electrotechnical Commission, and promulgated in I.E.C. Publication No. 27 (dated 1953): 'International Letter Symbols used in connection with Electricity'.

The four symbols criticized by Professor Cullwick (ϵ, ϵ_0, μ and μ_0) all appear in the above publication in the same sense in which they are used in B.S. 1991, and they appear similarly in the American standard ASA Z. 10.6—1948; 'Letter Symbols for Physics'.

In the simple form ϵ and μ, without any reference to subscript or free-space value, they also appear in ASA 10.5—1948: 'Letter Symbols for Electrical Quantities', and in the *Comptes Rendus* of the 1949 Conference of the International Union of Pure and Applied Chemistry, which records that these two symbols, among others, were agreed by the International Union of Pure and Applied Physics in 1948.

This consensus of opinion and usage is not lightly to be disregarded. Acceptance of the internationally agreed list of symbols by the B.S.I. means that the publications of The Institution, which follow the British Standard list, now use symbols of international currency. It means also that publishers of technical books will not be moved, as in the past, to abandon B.S. symbols in favour of I.E.C. ones on the grounds that they hope for a world-wide circulation of their books.

That similar symbols, differentiated only by a subscript, are now used to represent quantities dimensionally dissimilar is regrettable, and this consequence of following the I.E.C. was doubtless well known to those responsible for the production of B.S. 1991, but in my opinion the great advantages of international agreement were rightly held to outweigh this consideration.

(*b*) The terms themselves, *permittivity of free space* and *permeability of free space*, appear both in ASA Z. 10.6—1948, and in the English text of I.E.C. Publication No. 27, but since the titles to be used are primarily a matter for the English-speaking nations, it is probable that a change, if generally supported, could be introduced by agreement between the Americans and ourselves. In that event, the alternative titles suggested by Professor M. G. Say in 1947, namely *electric space constant* and *magnetic space constant* should not be overlooked.

I have not referred to the earlier part of Professor Cullwick's letter, interesting though it is, since an adequate discussion would require a full Institution paper.

Mr. Carr is a consultant.

Dr. E. M. Deloraine

discusses

PULSE TECHNIQUE

with particular reference to Line and Radio Communication

The radio-link repeater at Ikaria, Aegean Sea

On the 8th February, 1956, Monsieur E. M. Deloraine, Dr.Ing., Member, gave an admirable lecture on pulse technique to a very well-attended meeting of the Radio and Telecommunication Section of The Institution. The lecture as a whole, and particularly the remarks about 'a failure in planning', have created no little interest. Dr. Deloraine, who is Président de Laboratoire Central de Télécommunication, Paris, has prepared for the Journal a version of the lecture that is somewhat shorter than his original, and this is printed here, together with reproductions of a few of the slides shown at the meeting.

PULSE TECHNIQUE AND LINE COMMUNICATION

By pulse technique I mean here the transmission of intelligence through a process involving short bursts of energy. If we look as far back as 1753, we find that this is the oldest form of electrical communication, being the original method of telegraphy. I shall not cover here the progress of the art of the telegraph, so well known in The Institution. The point which must be remembered is that pulse technique in telegraph communication was developed quite early.

The technical achievements which followed Lord Kelvin's masterly researches on submarine telegraphy resulted in an advanced understanding of the principal factors affecting pulse transmission as known to-day. With one difference: the pulses used in telegraphy at that period and until recently have been pulses of comparatively long duration, i.e. in the range 1–50 millisec. With this telegraph background it is not surprising to find very early concepts of pulse telephony. The proposals of Charles Bourseul in August, 1854, and the experiments by Reis twenty-nine years later, described what we might be tempted to call to-day a two-level pulse-code-modulation system. The devices used to code and decode speech were, however, too crude to be satisfactory. It is with Alexander Graham Bell that we find the start of a technique which was going to influence from that time onwards all telecommunication. It involves spectra of amplitude-modulated continuous waves.

Quite early the telephone engineers made an effort towards determining the physical nature of speech and hearing, and the corresponding electrical characteristics of the translating devices from air pressure into electric current, or the reverse. They came rapidly to an excellent approximation of what was essential in speech, and in the nineteen-twenties most of the requirements to be fulfilled for satisfactory speech transmission were established. Active research then took place to achieve the transmission of such speech currents with a minimum of distortion. This study covered continuous-wave spectra under steady-state conditions. Circuits were defined by impedance parameters and frequency functions.

Multi-Channel Telephony

One of the important results of this work was the development of the technique of multi-channel telephony from 1925 onwards, with resultant massive economy in the cost of circuits in open wire or cable. Many important decisions were made which remain the basis of our present systems. These involved the principle proposed by John R. Carson of frequency translation of the original speech channels through modulators and band filters, accepting one sideband but eliminating the carrier; their assembly side by side in the frequency spectrum; the transmission over open wires or cables of the resulting group of channels; and the division back into the original channels through demodulators and filters.

These systems are generally known as single-sideband suppressed-carrier systems. These suppressed carriers, spaced 4 kc/s apart, with voice-frequency bands covering frequencies from approximately 250 to 3 400 c/s, constitute to-day the basic method of multi-channel telephony over multi-conductor or coaxial cables (Fig. 1).

Multi-Channel Telegraphy

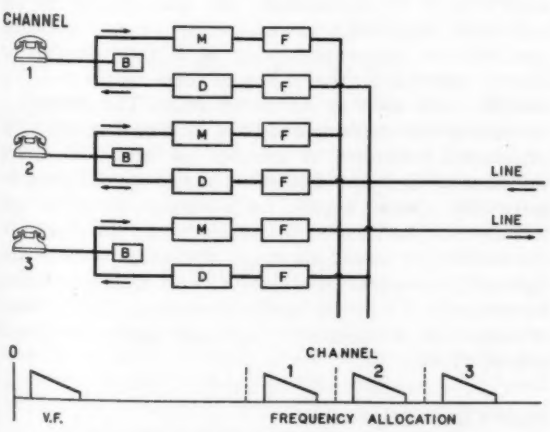
In the meantime efforts were made to lower the cost of circuits per telegraph channel. Telegraph pulses which are sent at the rate corresponding to hand-operated keys, or keyboards, with the use of either the Morse code or the 5-unit code, correspond to bandwidth requirements such that most overland open-wire or cable circuits can handle many telegraph channels. Various systems were developed in consequence, but the most successful method for improving circuit efficiency in telegraphy was found to be by translation of the pulses produced by the telegraph transmitters into trains of sinusoidal waves at voice frequencies that are suitably spaced: e.g. a spacing of 120 c/s, which would divide one v.f. band into 12–24 v.f. telegraph channels.

A Failure in Planning

The picture appears logical and orderly when we limit our analysis to multiplex telegraph transmission by frequency-spaced interrupted tones, and multiplex telephone transmission by frequency-displaced speech bands. In both systems we have only to handle low power levels of the order of 10 milliwatts over limited frequency bands. This, however, does not remain true when we consider the problem of connection to the telephone or telegraph switching equipment, especially with automatic switching.

It must be recognized that, whilst the telephone or telegraph transmission engineers saw from the beginning that they were not dealing with individual links, but with extensive networks, the switching engineers apparently thought for a long time, and indeed until recently, that their design work ended in practice when a few offices were interconnected over a limited area. They did not realize that sooner or later all subscribers, in one country or a group of countries, would form a single automatic network and that any subscriber should be able to call automatically any other subscriber.

As a consequence of the limitation in area erroneously



1 *Multi-channel telephony*

accepted, the interest of the switching engineer in pulse transmission remained high, because pulses in suitable groups are well adapted to operate selecting mechanisms, especially of the early stepping type. These pulses, produced by the dial at the rate of approximately 10 per second, are of character and duration quite unrelated in amplitude or frequency to telephone currents, and cannot be transmitted over the same frequency band.

Currents used for ringing at frequencies of the order of 20 c/s are also unrelated to speech currents, both in frequency and in amplitude. In consequence, a telephone link, almost from the start of automatic telephony, had to handle dial pulse trains and ringing currents, both at a high power level compared with that of the voice, and in an entirely different band of frequencies. Other signals were necessary as the technique developed, for control of the progress of a call, for supervision, for actuating the message-recording meters, etc. Most of these were again in the form of pulses, or series of pulses.

The difficulties found in designing long-distance telephone systems, capable of transmitting this variety of signals together with speech, became considerable. Impulses in the infra-acoustic band meant that the circuit should be able to transmit direct current and all frequencies from zero upwards. The ringing currents called for power-handling capacities of the order of 100 times that called for by speech. The powers corresponding to dialling impulses are of the same order. The design of cable circuits, magnetic-core transformers, amplifiers, filters, etc., capable of handling this range of powers and frequencies, caused difficulties so severe that it was found preferable to avoid them by the admittedly complicated procedure of transforming the signals at both ends of the circuit. The progressive complication of the various ensuing transformations of dialling, ringing and supervisory signals is hard to imagine. Almost every conceivable arrangement was developed, and what is more serious, was introduced in one or another telephone network. It was found desirable to translate these pulses or l.f. currents into v.f. trains of various characteristics, but of amplitudes comparable to speech currents, transmit them as such over the long-distance circuit, and translate them back to their original form at the end of the circuit.

The order which had been introduced in the planning of the carrier-telephone and -telegraph systems was increasingly lost in this phase of communication development, and the amount of equipment used in the transformation of signals into voice frequencies, and the reverse in a network, grew ever greater. An examination of the systems now in use reveals approximately forty different types, not compatible with each other. In a few the same signals are used in two different networks, but their significance is not the same.

Now that we can look at the past twenty years of telephone development we see that it might have been wiser to recognize from the start that signals originating or terminating at a telephone subscriber's set or telegraph apparatus should have characteristics comparable to

telephone currents. Alternatively, a unique method of translation at the central office should have been adopted, in order that offices of different types in any network should originate and receive the same v.f. signals. The problem of interconnection of offices or networks would then have been limited to the satisfactory transmission of telephone currents. It is quite possible that even now we may have to change our views and come back to what could have been the original concept. Several facts point towards this.

On one hand devices are available to-day which facilitate the solution to this problem. I have in mind the semi-conductor devices such as transistors. On the other hand there is the probable effect on systems of the introduction of electronic switching. The broad concept in switching can be that of an array of cross-points associated with means for selecting a suitable path through this array. The present technique of cross-points, i.e. metallic contacts, does not call for strict limitation of the power carried through the circuit. Such is no longer true with electronic cross-points of to-day—gas tubes or semi-conductor devices. They are sensitive to overloading, and if the power to be handled is limited to speech power, the design problem is greatly eased.

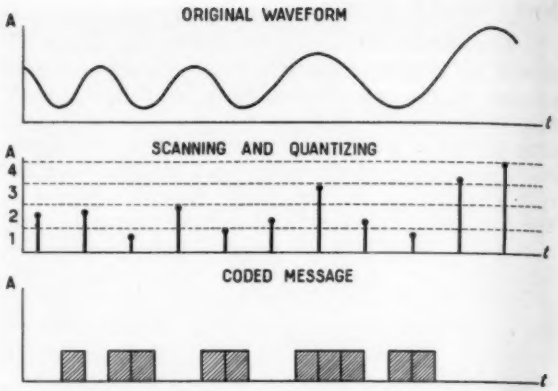
We find here a very illuminating situation. At long last the problem of the switching engineer and that of the transmission engineer come together and their interests converge. The indications are, in consequence, that the future of infra-acoustic pulse transmission in telephone networks is very uncertain; in fact efforts are being directed towards the complete elimination of such pulses.

This raises a question of the design of future telephone subscribers' sets and telegraph apparatus. The telephone set problem is greatly simplified by the introduction of transistors or similar devices. With the very modest power consumption of such elements, one can imagine the generation at the subscriber set of v.f. signals for controlling the selection, and the generation, on receipt of a calling signal at voice frequency, of a suitable audio signal replacing the present ringer. Telegraph apparatus similarly can be made to emit and receive v.f. signals.

PULSE TECHNIQUE AND RADIO COMMUNICATION

Let us now turn our attention to an entirely different aspect of pulse communication. There is a type of technique quite different in concept from the one described so far; it is covered by the broad term 'pulse modulation'.

This second concept may be typified as the opposite of the first one. It calls for the elimination from the line of currents of continuously varying amplitude, including speech, and their replacement by pulses carrying the intelligence. We see here a rather spectacular come-back of the telegraph art, with much shorter pulses however, bringing the necessity to re-study and improve the analysis and measurement of transient phenomena as



2 *Pulse-code modulation*

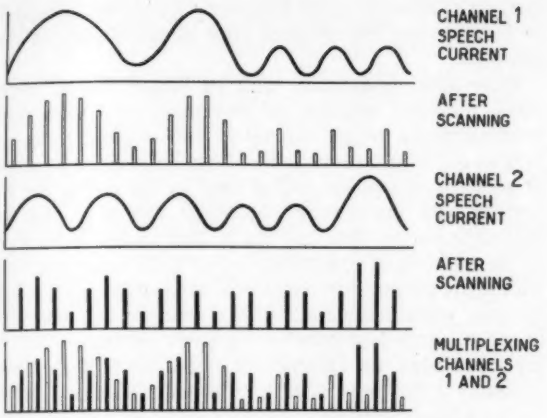
distinct from steady-state conditions. In line with this concept, an electrical signal of varying amplitude is translated into a series of pulses either equally spaced and of variable amplitude, or of constant amplitude, with a variation in other characteristics of the pulses—their width, their timing, their number, their presence or absence.

If we consider a signal of variable amplitude such as speech, the number of pulses per second necessary to define the waveform without distortion must be at least twice the highest frequency to be transmitted when the methods used involve a continuously variable parameter such as pulse amplitude, pulse width or pulse time. We need, in consequence, at least 7000 or 8000 pulses per second for a single telephone channel. It is possible also to translate speech signals into pulses of constant amplitude, width and spacing, the only variable being the presence or absence of pulses; but this requires a larger number of pulses per second.

This method of transmission applied to speech was conceived in 1937 by A. H. Reeves. It has since been known as *pulse-code modulation*. It involves three operations: the scanning at equal time intervals of the waveform to be transmitted; the quantization of the individual amplitudes corresponding to this scanning operation to the nearest value of a finite number of distinct amplitudes; the coding of these numbers with a suitable code such as an on-off code. The process is reversed at the receiving end (Fig. 2). The method, to be satisfactory, involves a number of amplitude steps sufficient to limit the distortion due to quantization to acceptable values. It calls for a number of pulses per second equal at least to the logarithm to the base 2 of the number of amplitude steps multiplied by twice the highest frequency to be transmitted per channel. Taking the example of a single telephone channel, and 32 steps of amplitude, the minimum number of pulses per second will be 40000.

Multi-Channel Operation

Multiplexing in this concept can be achieved either by



3 *Time-division-multiplex pulse-amplitude modulation*

frequency multiplexing first, and pulse modulation of the resulting a.m. wave, in which case the number of pulses per second is related to the highest frequency to be transmitted in the manner already described for a single channel, or by thinning each pulse considerably for each channel and by sending these in succession. The classic method is to send one after the other, one pulse for each channel over one scanning cycle, and then repeat the process (Fig. 3). In the example of one telephone channel with 8000 pulses per second, and 12 channels over one link, the total number of pulses per second will be 96000. The same with pulse-code modulation involves 480000 pulses per second. It will be appreciated that such pulses necessarily must not last more than a few microseconds. The translation of speech channels into pulses and the reverse process involve a form of synchronous distribution at both ends of the link.

When handling signals or ringing currents we find with pulse modulation the same kind of problems and limitations we experience with amplitude- or frequency-modulation.

Relative Merits of Pulse Systems and Others

Having referred to a number of modulation systems, I shall now attempt a general evaluation of their relative merits. Thorough studies have been made of this subject by qualified experts. I will refer to one only because it is exceptionally complete. This is 'Band Width and Transmission Performance' by C. B. Feldman and W. R. Bennett.* I shall cover only some essential points.

It is generally possible to obtain transmission improvements by increasing the bandwidth used per channel, one exception being the single-sideband a.m. carrier systems, in which such advantage cannot be obtained to a marked degree. In pulse systems one can trade bandwidth against noise or distortion. This is also true of f.m. systems, both with frequency modulation of individual channels and frequency modulation of a group of channels.

One important advantage in a.m. frequency-division-multiplex systems is that the peak power handled by one common element is only a fraction of the sum of the peak powers of individual channels: this is more so as the number of channels increases. The parallel advantage in time-division systems with pulses of constant amplitude is due to each channel being capable of full modulation without increase of the load on the common element. In consequence one can introduce amplitude compression, which increases the average modulation in the input of the system, and gives a corresponding expansion at the output with marked advantage. These devices can be individual per channel or common to all channels.

In comparing the two classes of systems it is consequently desirable that each be credited with its own intrinsic advantages. The choice between frequency-division systems and time-division systems is influenced by the characteristics of the transmission medium within the band to be used. Amplitude distortion and phase distortion, for example, affect the systems differently. One should not conclude that time-division methods to be justifiable must always make use of larger bands than the frequency-division systems. Feldman and Bennett indicate that when the frequency space necessary to avoid mutual interference between systems is taken into account, certain wide-band methods less vulnerable to interference may be as efficient in use of frequency space as other narrower-band multiplex methods, or even more efficient.

Systems using Pulse Modulation

It will be understood from the above that even with an incomplete understanding of all factors affecting the choice between frequency-division and time-division systems, radio engineers would naturally be the first to try to derive advantages from the use of time division, because they well knew that their medium of transmission, the radio path, was far from noiseless, distortionless and stable in characteristics.

The first appearance of pulse equipments in the field of telephony was the British military set known as the No. 10 set, which was used on the Continent of Europe after the landings in 1944. It was an 8-channel equipment using pulse-time modulation. After the war many radio links using pulse-multiplex systems came into the field. The interest of their sponsors was in general to arrive at a multiplex system which might be less critical and simpler than its frequency-division-multiplex counterpart. A number of combinations were used, most of them with pulse-time modulation of the voice channels and amplitude modulation of the carrier. The counterpart with pulse-amplitude modulation of the voice channels and frequency modulation of the carrier is also used, and appears to gain favour as being more adapted to the use of instantaneous compandors and more economical of bandwidth than the pulse-time modulation system.

* *Bell System Technical Journal*, 1949, **28**, p. 490.

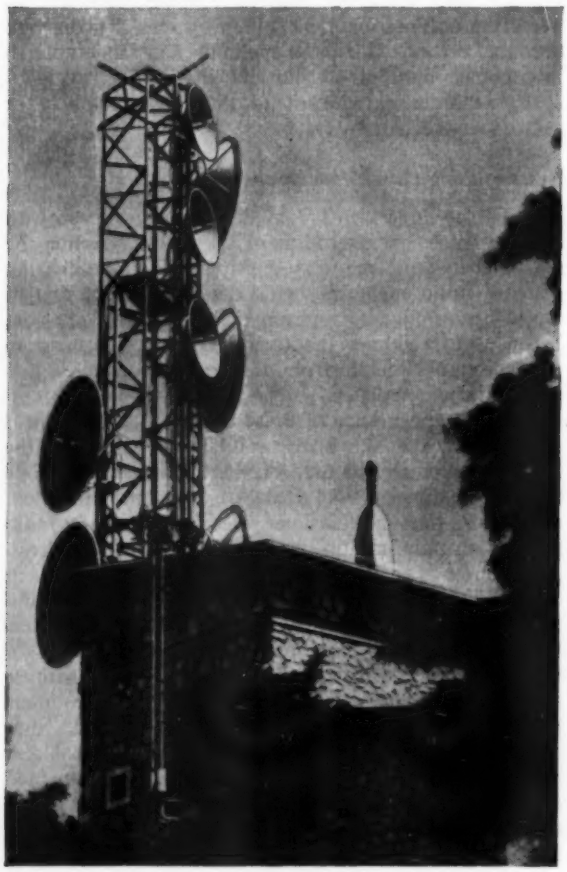
The designers found, as expected, that the above pulse systems, when compared to frequency-division systems, are not critical in link requirements. The systems will accept greater length of antenna feeders, poorer impedance matching of line to antenna, than frequency-division systems with frequency modulation of the carrier. The latter systems are also more sensitive to amplitude and phase distortion than time-division systems.

Fading may be minimized in pulse systems, particularly over paths over water, by the use of diversity reception, simply by paralleling the automatic gain control and the output of the two receivers. In frequency-division systems it appears necessary to measure the two levels and to commutate at high speed from one receiver to the other.

An important point in network planning is that the channel grouping of a frequency-division system is usually the same as used on cable or open-wire carrier systems. The interconnection can be made at carrier frequency. Such is not possible in many pulse-modulation systems starting at voice frequency. It is then necessary to interconnect the systems after demodulation of the channels.

The radio station at Mt. Parnis, Greece

In this station eight antennae relay three radio channels in three directions, with space diversity on two of these directions.



Pulse-code modulation with its binary 'on-off' code takes repeaters capable of re-timing, re-shaping and re-transmitting pulses exactly in the original form, as long as the repeater is capable of recognizing the presence or absence of a pulse, and as long as the timing can be derived with the required accuracy over a number of incoming pulses. One can see in this system a solution to the problem of transmission over a distorting medium with many repeaters in the circuit. Pulse-code modulation systems, whilst having attracted a great deal of attention in the research laboratories, have not yet been used, to my knowledge, on commercial radio links. The reason probably is that most pulse links have not been engineered for very long distances.

It will be of interest to give the results of a recent survey I have made of the extent to which pulse systems are in commercial use to-day. It will be appreciated that the figures quoted below represent minimum values, for it is probable that a number of existing links did not come to my attention.

Pulse-Multiplex Radio Links in Operation, January 1956

COUNTRIES	TERMINALS OR REPEATERS	ROUTE-MILES	CHANNEL-MILES
U.S.A. and Mexico	330	8246	89120
Germany	126	2340	54000
Greece	34	1250	15500
Austria	17	282	5805
Australia	16	241	5543
Canada	15	244	7962
Belgium	14	225	8800
Spain	2	25	680
Switzerland	2	8	96
Total	556	12861	187506

Many more radio links of this type are in the process of being ordered or are already in construction. A minimum figure of another 100 terminals or repeaters and 50000 channel-miles can be quoted safely to-day. Whilst the largest proportion will be found in the United States, Belgium is probably second with about 13600 channel-miles, Spain and Germany next, each with 9000 channel-miles, and Austria fifth with 4500 channel-miles.

Waveguides

Before leaving this subject I should like to refer to another method of transmission, namely long-distance waveguides. An analysis of the electric phenomena present in a round metallic tube with signals propagated as circular electric waves was given by S. E. Miller.*

* 'Waveguide as a Communication Medium', *Bell System Technical Journal*, 1954, 33, p. 1209.

With circular electric waves the attenuation decreases as frequency increases. This makes the mode of propagation most attractive for long-distance communication. Signals are distorted however, owing principally to the transfer of the energy in the circular wave to other waves, because of minute imperfections in the waveguide, and after a time delay some of this energy is transformed back to the original wave. This results in a large interference with the original signal. Whilst this difficulty can be minimized, it remains a serious obstacle to the usual methods of transmission, sensitive to such interference. In consequence, the type of modulation likely to be used in these waveguides, according to Miller, is pulse-code modulation, as it makes it possible to regenerate the signal at each repeater. To give a few orders of magnitude quoted by Miller: with a pipe of 2 inches diameter, the attenuation is of the order of 2 dB/mile for a carrier frequency of 50 000 Mc/s; a repeater spacing of 25 miles is considered; and the frequency band that might be exploited is 35 000–75 000 Mc/s, with a base bandwidth of 500 Mc/s.

Other engineers have suggested that we can expect such waveguides to transmit tens of thousands of telephone channels together with hundreds of television programmes. Consider, for instance, the combination now used on long-distance coaxial cables in the United States of 900 telephone channels and one television channel over an 8 Mc/s band; if the transmission of this spectrum is by pulse-code modulation with 128 levels, the number of pulses will be $8 \times 2 \times 7$, or 112, million per second. This means pulses of a few millimicroseconds' duration, and might require in practice a frequency band of 200 Mc/s. In view of probable difficulties in equalization, these channels may have to be transmitted over separate carriers on a frequency-multiplex basis, with base bands of about 500 Mc/s, which would permit the transmission of 80 such channels, i.e. approximately 12 times the channel-carrying capacity of our present type of multi-core coaxial cable.

It will be clear from this last example that one may be driven, for valid reasons, to a triple combination of a frequency-division system with a time-division system and again with a frequency-division system. There is no simple rule in selecting the field of application of these systems—one or the other may be justified economically, depending on the characteristics of the transmission path and the conditions to be met. Sometimes both systems are combined with advantage.

OBITUARY

ARNOLD CHRISTIE EDEN

Arnold Christie Eden, B.SC., who died on the 24th February, 1956, was born at Bath on the 17th July, 1902. He received his early education at a private school and at the Wiltshire County Secondary School, Devizes, and his technical education at Bristol University, where he took a course in electrical engineering and obtained a B.Sc. degree in 1921. After a year's research on gas flow in two-stroke engines, he obtained practical training at the works of the Metropolitan-Vickers Electrical Co., Manchester, from 1923 to 1925.

In 1925 he entered the service of the Yorkshire Electric Power Co., acting first as Assistant Testing Engineer and later as Assistant Mains Engineer. In 1930 he received an appointment as Mains Engineer and Chief Assistant to the General Manager of the Mid-Cheshire Electricity Supply Co., Northwich. He served in that capacity until 1945, when he became Distribution Engineer of the Mid-Cheshire Co. and its allied concern, the Mersey Power Co., which jointly served the Mid-Cheshire salt district, a large rural area and the industrial belt on Merseyside. On Vesting Date in 1948, Mr. Eden was appointed Assistant Sub-Area Engineer, and District Engineer of the Warrington and Northwich Districts, of the Merseyside and North Wales Electricity Board. In 1949, he moved to Cambridge to take up an appointment with the Eastern Electricity Board as Sub-Area Engineer in the Fens Sub-Area, the position he held at the time of his death.

Mr. Eden had a thorough knowledge of the business and administration of an electricity supply undertaking, and, during his service with the Mid-Cheshire and Mersey Companies, and later with the Eastern Electricity Board, he was responsible for the supervision of large urban and rural extensions and main transmission lines. After nationalization of the supply industry many important extensions were carried out by the Eastern Electricity Board in Cambridgeshire and Huntingdonshire under his supervision.

He was respected and admired by all who worked with him and under him, and his likeable personality ensured a happy and contented staff and friendly business relations. He will be much missed by his colleagues and friends. He suffered from ill health for some years but he had a happy home life. He leaves a wife and two daughters. He was a regular attendant at his Church and a valued helper in all good causes. At his funeral at Shelford, Cambridgeshire, the Vicar of the parish spoke these words:

> Arnold Eden would have been the last to wish anything said of him, in praise or appreciation, in public. But something should be said now, however briefly . . .
>
> It may be said of him that he was a brilliant engineer; a wise and understanding man to work for or with; but perhaps beyond that, and including it, it should be said that he was a very modest, unassuming Christian gentleman.

He joined The Institution as a Student in 1920, and was elected a Graduate in 1929, an Associate Member in 1931 and a Member in 1943.

J. E. N.

ERIC CHRISTOPHER STANLEY MEGAW

Eric Christopher Stanley Megaw, M.B.E., D.SC., who died on the 25th January, 1956, was born on the 19th January, 1908. His unexpected death robbed the nation of one of its leading scientists and The Institution of one of its best-loved members.

Dr. Megaw had already proved himself to be a brilliant research engineer, whose advice was constantly sought on all scientific matters and whose judgment was always regarded with respect.

Educated at Campbell College and the Queen's University, Belfast, from 1921 to 1928, he studied subsequently with Professor C. L. Fortescue at the City and Guilds College, where he was a Beit Scientific Research Fellow. He joined the Research Laboratories of the General Electric Co. in 1930, and quickly established himself in the field of electronic valves, making valuable contributions to the design of all types of centimetre-wave devices and particularly magnetrons. In 1936 he began development work for the Admiralty on valves and other electronic equipment at the G.E.C. Laboratories, and three years later he was appointed leader of a team engaged on this. The realization, at a critical stage in the nation's fortunes, of a cavity magnetron capable of practical manufacture owed much to him. His work on the propagation of ultra-high-frequency waves is now part of the literature of the subject. He served with distinction on various war-time radio committees, for his interests spread far beyond electronic devices. He was made an M.B.E. in 1943.

In 1946 he joined the Admiralty service as the Superintending Scientist at Witley extension of what is now the Admiralty Signal and Radar Establishment, where he continued to direct and to take an active part in propagation studies. In 1951 he was appointed the Director of Physical Research, a post which he held until his death. Dr. Megaw was Chairman of the Radio Section of The Institution in 1952–53. During his tenure of office he did much to stimulate and to encourage radio engineering. Slightly diffident as a Chairman, he will always be remembered for his friendly and penetrating comments.

To those of us who worked intimately with Eric Megaw, his loss is particularly severe. He never considered himself, putting the good of the Service and his staff before all else. Yet his interests were very wide; as he once said of himself, he might have been a poet instead of a scientist. His widow, his two sons and his many friends all over the world will long mourn him.

He joined The Institution as a Student in 1928, and was elected a Graduate in 1929, an Associate Member in 1937 and a Member in 1947. He wrote several papers that were published in the *Journal*; for the one on 'An Investigation of the Magnetron Short-Wave Oscillator' he was awarded the Duddell Premium in 1933, and a second Premium in 1946 for 'Experimental Studies of the Propagation of Very Short Radio Waves'. He served on the Radio Section Committee 1942–45, 1946–47, and 1948–49. He was a Vice-Chairman 1950–52, and, as noted above, Chairman 1952–53. J. T.

ALFRED MAURICE PATON

Alfred Maurice Paton, B.A., B.SC., who died on the 18th February, 1956, was born on the 22nd December, 1878, in Adelaide, South Australia.

He spent his schooldays at Prince Alfred College, Adelaide, before proceeding to the University of Adelaide, where he graduated in 1898 with a B.Sc. honours degree in mathematics and physics. In 1899 he came to England, and went up to St. John's College, Cambridge University, where in 1901 he obtained a B.A. degree with honours in the Mechanical Sciences Tripos.

His practical training in industry began in 1901 with the Westinghouse Electric and Manufacturing Co. at Pittsburg in the United States. He returned to England in 1903, and was engaged in design work in the electrical engineering departments of the associated British company at Manchester. There followed a year's work in the firm's office in Newcastle, on the preparation of tenders and other commercial duties connected with the installation of machinery and plant in industrial works, collieries and shipyards; early in 1906 he went for nearly a year to the Royal Arsenal at Woolwich, where he was occupied with the design and manufacture of miscellaneous war materials and experimental work.

From December, 1906, to 1915, he held an appointment with Cleveland and Durham Electric Power Ltd. at Middlesbrough, as Consumers' Department Engineer dealing with supplies to the larger industrial consumers on Tees-Side. In 1915 he moved to Bradford, where he was employed by the Snyder Electric Furnace Co. on the design and installation of equipment for steel production. He left in 1917 to join the British Thomson-Houston Co. at Rugby to take up commercial engineering work in the Contract and Turbine Sales Department. In 1917 he came back to Tees-Side to act as a Consulting Engineer to many shipyards and industrial firms, and was responsible, in particular, for the electrical installation in the shipyard of the Ropner Line and William Gray and Co. Ltd.

Mr. Paton returned to the supply industry in 1926, becoming, a year later, the Senior Power Department Engineer for Cleveland and Durham Electric Power Ltd., later to be absorbed in the North-Eastern Electric Supply Co. For some fifteen years until his retirement in 1941, he was engaged not only in the negotiations of industrial supplies on Tees-Side, but also in the development of power supplies in South Durham and North Yorkshire.

Like many of his colleagues, during the Second World War, he tendered his services to the War Office, and he worked in London as Deputy Assistant Director of Contracts, Ministry of Supply, for some three years before finally retiring to his home at Crakehall, North Yorkshire.

Mr. Paton served on many Tees-Side Committees: he was Chairman of the Publicity Committee of the Tees District Development Board; a Member of Council of the Tees-Side Chamber of Commerce; a Member of the Governing Council of the Constantine Technical College at Middlesbrough; and a Member of Council and Past-President of the Cleveland Scientific and Technical Institution.

His outdoor recreations included golf, tennis, motoring and fishing, and he became an accomplished violin player.

In 1913 he married Doreen May Norman, who died in 1954. There are three surviving children, a son and two daughters. Both Mr. and Mrs. Paton are buried in the Churchyard at Hornby, North Yorkshire, in sight of the Castle and in the dales they loved so much.

Mr. Paton joined The Institution as an Associate Member in 1919 and was elected a Member in 1921. He served on the Tees-Side Sub-Centre Committee 1919–22 and 1925–26. He became a Vice-Chairman of the Committee in 1922, and was Chairman 1924–25. A paper by him entitled 'The Professional Status of the Engineer' was published in the *Journal* in 1925.

He was also an Associate Member of The Institution of Civil Engineers. A. S. R.

LONDON'S NEW TELEVISION STATION

A Short Description of the Crystal Palace Equipment and its Background

Out of the ashes . . .

The steel monument to 1956 rises among the neo-Grecian relics of a bygone age.

SOARING upward from one of the highest points of the South London skyline, the slender parabolic skeleton of a new tower, as yet incomplete, locates a new addition to that newest form of mass-entertainment, television. Symbolic of its decade, it might well have grown as a monument to the power which has enthralled the people of these isles more swiftly and more surely than anything before in their history, and has wrought there a change of outlook as great as the change it has wrought on our urban landscape with its patchwork of dipolar forests dutifully facing the new Mecca.

Because the television service has so recently grown from a Metropolitan prerogative to a nation-wide necessity, there is a temptation to regard it as an invention of this decade; so it is not without point to look back at some high-lights of its development from the germination of the idea in the minds of men to its flowering as the colossus of public entertainment: its future has already been considered in other pages.

History

In 1873, at the Valencia terminal of the Atlantic telegraph cable, an operator named May reported that the behaviour of some selenium resistances varied with the amount of light falling on them. This discovery aroused great interest, for here was a means by which visible pictures might be reduced to electrical impulses and transmitted over long distances, and, indeed, Sir Shelford Bidwell demonstrated primitive visual telegraphy to the Physical Society in 1881. There was still far to go before these ideas could become television, for a picture must be reduced from three dimensions to two before it can be transmitted electrically; this was finally accomplished—and still is—by dividing the picture into small elements, transmitted consecutively. The means of doing this came in 1884, when Nipkow invented the disc on which the early television systems were based, while five years earlier Sir William Crookes had first demonstrated the cathode-ray tube which was to become the heart of television. But not until 1908 did science find a way of amplifying successfully the small electrical signals available, for in that year A. A. Campbell Swinton described in *Nature* the high-sensitivity device with an inherent electrical storage which was the forerunner of the modern camera tube.

The tools were there and the target was visible. Now the idea had to become a reality. The name which came before the public first was that of a Scottish visionary, James Logie Baird, who, in 1926, produced a television system which gave a tolerably faithful reproduction of a picture transmitted by a line connecting the transmitter and the receiver. Baird was hailed as the 'father of television', and it was not until this present decade that public acknowledgement was made to the men whose systems and developments, rather than Baird's, have stood the test of time and public demand.

The Beginnings of a Service

Because the somewhat elementary definition of Baird's system demanded only a narrow bandwidth, it seemed feasible to radiate television signals over a normal sound broadcasting system; so, in 1929, the B.B.C. began daily transmissions from its 2 kW transmitter in Oxford Street, the studio being at Baird's laboratory in Long Acre. Thus was inaugurated the world's first public television service. With 30-line scanning, 12½ pictures per second and no sound it was undoubtedly crude; with transmissions of only a half-hour's duration on five days a week it was experimental. But it was a public television

service, and it grew from strength to strength; moving the transmissions to Brookman's Park enabled the associated sound to be transmitted with the picture from the 14th April, 1930; the B.B.C. took control, installed the latest transmitters, and equipped studios in Broadcasting House in 1932 and an even larger studio at 16 Portland Place in February, 1934.

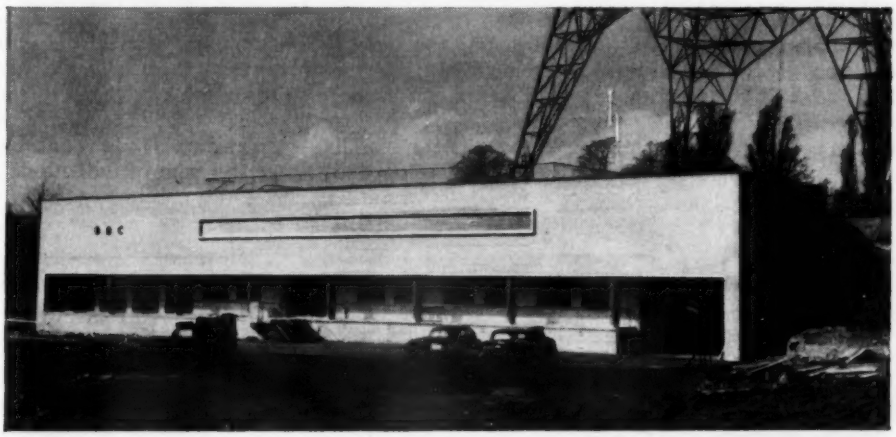
Progress had not halted because a regular service had begun: indeed, this provided a considerable stimulus to development, for, above all, it was clear that the flicker and poor definition of this the first system would be intolerable to a really wide public. Moreover, the term 'high definition' was heard increasingly among the select circle of engineers and viewers. In May, 1934, the Postmaster General appointed the Selsdon Committee to inquire into the merits of alternative systems then available, and as a result of the obvious imminence of this new, high-definition, television, the London station closed down on the 11th September, 1935.

Backed by a growing wealth of engineering experience, and in full cognizance of the many factors which would help to provide the best possible service to the people of Greater London without undue expense, the Selsdon Committee recommended that a new station, complete with its own studios and transmitters, should be established at Alexandra Palace. Since there was still considerable doubt about the best technical system, the Committee laid down minimum standards, from which the B.B.C. decided to install two systems to radiate alternately—Baird's 240-line 25-frames/sec sequential system (the minimum standard) and a 405-line 50-frames/sec interlaced system developed conjointly by the Marconi and E.M.I. Companies. Experimental radiations began in August, 1936, and the Postmaster General formally opened the world's first high-definition television service on the 2nd November of that year.

The 20 years which followed were years of change and upheaval; indeed the new station was barely half a year old when it underwent its first operation, for the 405-line system proved so markedly superior to its bedfellow

BIRMINGHAM
NUNEATON
COVENTRY
RUGBY
KETTERING
NORTHAMPTON
LEAMINGTON
WARWICK
Stratford on Avon
Evesham
Chipping Campden
Banbury
Buckingham
Bedford
Biggleswade
Royston
Cambridge
Huntingdon
St. Neots
Ely
Chatteris
Newmarket
Bury St. Edmunds
Thetford
Diss
Lowestoft
Beccles
Bungay
Halesworth
Southwold
Stowmarket
Debenham
Saxmundham
Aldeburgh
Woodbridge
Orford
Ipswich
Hadleigh
Felixstowe
Harwich
Colchester
Manningtree
Sudbury
Haverhill
Saffron Walden
Thaxted
Halstead
Braintree
Great Dunmow
Bishops Stortford
Frinton on Sea
Clacton
Witham
Chelmsford
Maldon
Burnham on Crouch
Ingatestone
Brentwood
Romford
Upminster
Tilbury
Southend on Sea
Sheerness
Gravesend
Rochester
Chatham
Gillingham
Sittingbourne
Faversham
Canterbury
Whitstable
Herne Bay
Ramsgate
Margate
North Foreland
Deal
Dover
South Foreland
Folkestone
Hythe
New Romney
Rye
Dungeness
Ashford
Tenterden
Headcorn
Maidstone
Tonbridge
Tunbridge Wells
East Grinstead
Crowborough
Mayfield
Uckfield
Robertsbridge
Hastings
Bexhill
Eastbourne
Beachy Head
Newhaven
Hove
Worthing
Brighton
Lewes
Hailsham
Arundel
Chichester
Littlehampton
Bognor Regis
Selsey Bill
Portsmouth
Gosport
Fareham
Havant
Emsworth
Southampton
Fordingbridge
Romsey
Peterfield
Alresford
Winchester
Andover
Basingstoke
Aldershot
Guildford
Reigate
Redhill
Horsham
Haslemere
Crawley
Farnham
Alton
Whitchurch
Ludgershall
Salisbury
Wilton
Wylye
Blandford
Bournemouth
Poole
Wimborne Minster
Brockenhurst
Lymington
Lyndhurst
Ringwood
Christchurch
Yarmouth
Newport
Sandown
Ventnor
St. Catherine's Point
Swanage
Ryde
Cowes
Shanklin
Reading
Henley on Thames
Maidenhead
Windsor
Slough
Staines
Wokingham
Bracknell
Sunningdale
Weybridge
Woking
Camberley
Guildford
Epsom
Sutton
Croydon
Purley
Caterham
Warlingham
Redhill
Oxford
Abingdon
Wallingford
Thame
Aylesbury
Berkhamsted
Hemel Hempstead
St. Albans
Hertford
Watford
Enfield
Cheshunt
Chesham
Epping
Harlow
Bishop's Stortford
Luton
Dunstable
Leighton Buzzard
Bicester
Woodstock
Chipping Norton
Stow on the Wold
Cheltenham
Tewkesbury
Evesham
Pershore
Droitwich
Bromsgrove
Redditch
Alcester
Kenilworth
Coventry
Nuneaton
Lutterworth
Market Harborough
Oundle
Wellingborough
Towcester
Brackley
Witney
Faringdon
Lechlade
Cirencester
Malmesbury
Swindon
Marlborough
Hungerford
Newbury
Basingstoke
Andover
Romsey
Fordingbridge
Ringwood
Wimborne Minster
Poole
Bournemouth
Christchurch
Yarmouth
Newport
Sandown
Ventnor
St. Catherine's Point
Swanage
Ryde
Cowes
Shanklin
Portsmouth
Gosport
Fareham
Havant
Emsworth
Chichester
Littlehampton
Bognor Regis
Selsey Bill
Arundel
Worthing
Hove
Brighton
Lewes
Hailsham
Bexhill
Hastings
Eastbourne
Beachy Head
Newhaven
Seaford
Peacehaven
Rottingdean
Shoreham
Steyning
Billingshurst
Petworth
Midhurst
Haslemere
Godalming
Guildford
Woking
Weybridge
Staines
Windsor
Slough
Maidenhead
Henley on Thames
Wallingford
Abingdon
Ox

that transmissions with the Baird equipment ceased in February, 1937. The exigencies of war stopped transmissions on the 405-line system while effort was diverted to more vital work, and when, after nearly seven years of silence, Alexandra Palace went 'on the air' again it was to be, not the only high-definition station in the world, but grandmother to a growing family of television transmitters spreading across the world. By the middle fifties the B.B.C. and industry had extended the coverage of the television service to include the greater part of the



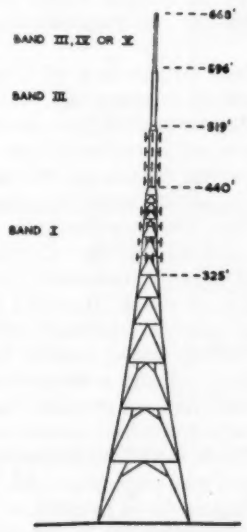
2 *The clean simplicity of the façade will enhance the terrace when the landscape gardening is completed*

country, and it was clear that the London station was due for replacement. True, it still offered a very acceptable service to some 12½ million people, with a standard of continuity which was a fine tribute to the design and workmanship of the original equipment. But the pattern of living itself had changed, for the vast sprawl of habitation which had become intimately linked with the metropolis, irrespective of fiscal boundaries—had spread deep into the south; and the fast-expanding towns on the Channel coast were but poorly served by Alexandra Palace.

The Decision to Move

Thus, in July, 1953, the great English manufacturers of television equipment received invitations to tender for the supply of a new station, comprising two vision transmitters each with an output of about 12 kW (with the possible subsequent addition of amplifiers to raise this to 50 kW each) and the associated sound equipment. Geographic considerations dictated a site to the south of the Thames, and after extensive field-strength surveys it was agreed that an aerial up to the maximum height permitted by the Ministry of Transport and Civil Aviation, erected in the grounds of the old Crystal Palace, would give the optimum performance and offer television to some 15 million homes (Fig. 1). Now the L.C.C. have extensive development plans for the Crystal Palace grounds, but they offered a 2-acre site to the north-east of the upper terrace on condition that the building was buried to afford public access to the terrace. Thus, only the facade (Fig. 2) of the new station is visible and can be lit naturally; the remainder needs artificial light and ventilation, which adds to its cost. Moreover, the restrictions on the site precluded the erection of the slim stayed mast which had proved so successful in the provinces, so that the more expensive self-supporting tower had to be used. Air-navigation requirements limited the height of the top to 1050 ft above sea-level, which meant that the tower itself could rise no more than some 690 ft above its base. With the types of aerial and transmitter envisaged, the design was such that an effective radiated power of 500 kW might eventually be transmitted, although initially only some 200 kW—compared with the 34 kW of the original Alexandra Palace installation—would be radiated. The probable location of the aerials is shown in Fig. 3.

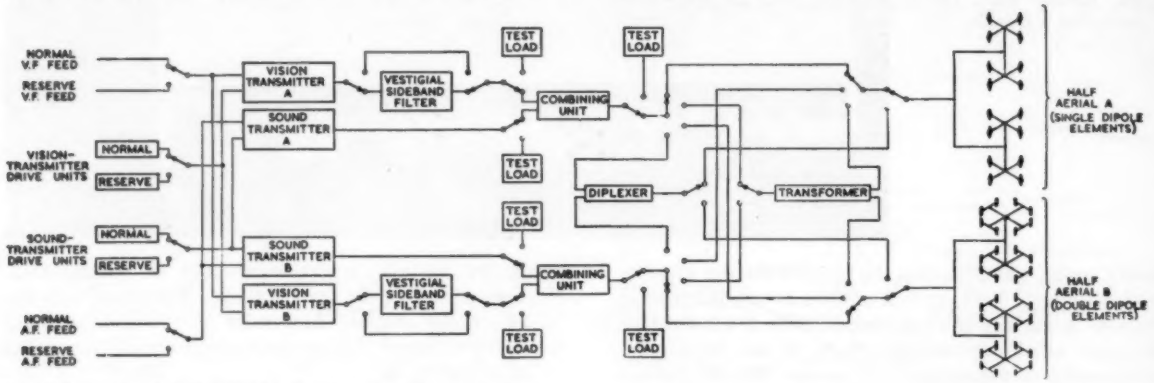
The contract for the transmitting equipment was awarded to one of the organizations whose transmitters were then still giving yeoman service at Alexandra Palace.



3 *Proposed allocation of aerial space on the new tower*

Although the old station radiated a full double-sideband signal, it was agreed that its successor should use the vestigial-sideband signal which had proved so effective and useful in the post-war provincial stations; a few viewers would need their receivers modifying because of this, but the majority would be unaffected, since all receivers made since 1950 were designed for vestigial-sideband working.

The main design characteristics of both sound and vision transmitters were conditioned by the paramount importance of utmost reliability, so that there should be as few breaks in transmission as possible. To secure this it was decided to install duplicate equipment and to construct the aerial and feeder systems in two halves; thus, should a fault occur in one of the transmitter chains, the remaining unit could immediately be switched over to feed both halves of the aerial, while a fault in one aerial feeder chain would see both transmitters feeding one



4 *Schematic of duplicate chains of transmitting equipment*

half-aerial (Fig. 4). In this way the strength of the signal would be reduced by an amount barely noticeable on most receivers, and the programme would not be interrupted.

To the manufacturer fell the task of interpreting the transmitter requirements economically, but there were many problems: the 405-line British system, with its positive modulation on vision and amplitude modulation on sound, has limited use outside the British Isles (only New Zealand has, in fact, accepted this standard). The export markets, which the manufacturers must serve, have the 525-line F.C.C. or the 625-line C.C.I.R. standards, both with negative modulation on vision and frequency modulation on sound. It would doubtless be simplest to design a 'one-off' equipment and leave it at that, but such an attitude grows steadily less tolerable in a highly competitive industry seeking world markets. Again, while the B.B.C. had not specified that the equipment should be suitable for colour television, the manufacturers believed that it would be demanded in Britain before the new station was many years old. Should they take cognizance of this, so far as possible, or should they adhere to the original specification? True, there could be no question of supplying a station to radiate any form of complete colour-television signal, but there were many items of equipment which could still be used for colour transmissions eventually—provided that they had the power capacity. So the designers calculated the additional power requirements for the N.T.S.C. type of colour signal—which seems the one most likely to be used—and designed their equipment accordingly.

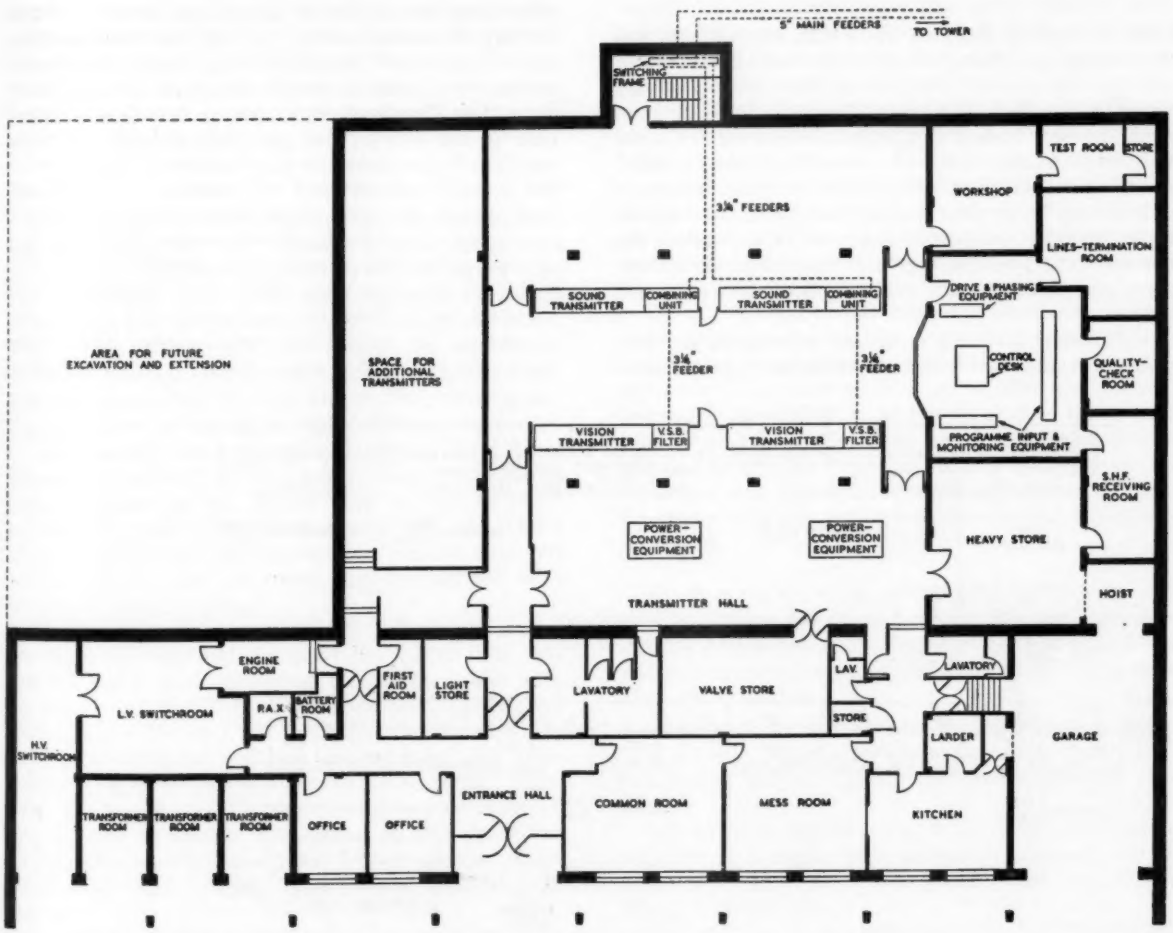
The Vision Transmitters

The design of a vision transmitter is largely governed by the availability of suitable valves. All the provincial stations commissioned during the early fifties had been based on triodes, but driving and modulating them demanded considerable power. When the manufacturers began to settle the preliminary design bases they found available the CR192, an air-cooled tetrode with an anode dissipation of 10 kW. Here was a real advantage, for the greater gain of the tetrode would mean fewer stages of amplification, and the elimination of water cooling would ease the maintenance problem. So it was decided to base the vision transmitter on tetrodes, and this permitted an increase of power above that called for in the specification. Consultation brought rapid agreement from the B.B.C. to accept 15 kW instead of 12 kW sets, while the new design enabled outputs up to 18 kW to be obtained on standards less power-consuming than the British. Moreover, the use of tetrodes enabled the whole of the r.f. amplifier to be fitted into a cabinet 7 ft high, 2 ft 6 in. wide and 3 ft 9 in. deep; and since the modulator, together with much of its power-supply and the waveform-correction equipment, could also be accommodated in a similar cabinet with equally good accessibility, it became feasible to assemble the station from a set of similar-sized 'packaged' units (Fig. 5). Not only did this ease the problems of architectural design, but also it will greatly facilitate the future extension of the station (Fig. 6). Equally, of course, it greatly simplifies the problems of packing equipment exported to distant countries—as the manufacturers are indeed doing with equipments for four stations in Australia.

The station is connected for complete push-button operation from a console (Fig. 7) set at one end of the

5 *The main transmitter hall, facing the control room*

The vision transmitters are on the right, and the sound transmitters on the left.



6 *Layout of the transmitter building*

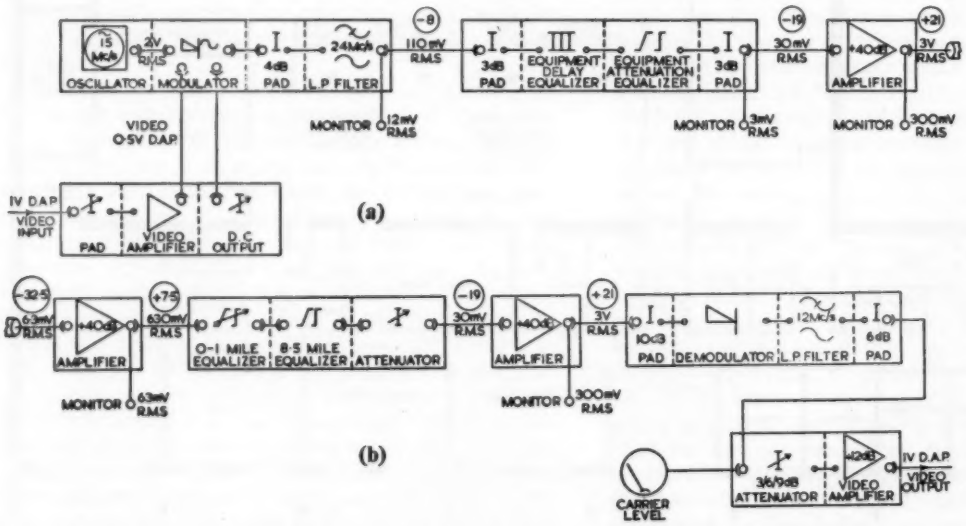
The fraction of the building actually occupied by the transmitters and associated equipment is remarkably small.

7 *The control console, with the drive and phasing equipment on the right*

main transmitter hall, so that, with all controls and monitoring equipment within arm's reach, one operator can run the station comfortably. The keynote of the whole design is reliability, and every effort has been made, in every item of equipment, to ensure that Crystal Palace will remain on the air—even if at slightly reduced power—no matter what happens. Efforts have been made to avoid any single piece of equipment becoming essential to the operation of the complete station, and where this has not been possible, e.g. with the master oscillators, complete spares are ready to be switched in at a moment's notice.

Monitoring devices give instant warning of any programme degradation, which can immediately be corrected from the console; a fault in any part of the transmitter radiating is made instantly apparent, and a push-button switches the service to the other without effort and without being apparent to the viewer; the engineers can thus seek out and rectify a fault with unhurried precision rather than in the haste demanded by the need to resume normal service as soon as possible. Small wonder indeed that both the B.B.C. and the manufacturers should have serious thoughts about unattended stations and remote control. When a fault does occur, indicators on the control desk locate the part of the equipment in trouble, while further indicators on the transmitter fronts show, in the particular unit, the nature of the fault. Once the faulty cubicle has been located and isolated from the mains, interlocks built into the door handle ensure that no exposed terminals carry more than 50 volts and that all smoothing condensers are discharged and earthed before the door can be opened.

Under normal operating conditions the sound programme comes from Broadcasting House over Post Office land lines, while the vision signal makes the 9-mile journey via coaxial cables, with special terminal equipment (Fig. 8) built by the B.B.C. to secure the absolute minimum of signal distortion during the journey. Inside the station the vision signal passes through the control desk to the clamp-pulse generator and the correction unit: the former generates a pulse which is applied to all the clamping circuits and will remain correctly timed, even though the input signal, from which it is derived, may contain considerable low-frequency distortion, hum or noise pulses; the correction unit stretches the synchronizing pulses, clips them to the level required to give standard output from the transmitters and applies pre-correction for transmitter non-linearity. The output from here is fed to a pre-amplifier, to raise the signal



8 *Schematics of the terminals of the vision link between Broadcasting House and Crystal Palace*
(*a*) Transmitting terminal. (*b*) Receiving terminal.

level, which is then clamped at black level. The clamped signal is amplified by a shunt-regulated amplifier, and is fed to the grid of the modulated amplifier via a shunt-regulated cathode-follower designed to meet the heavy reactive-power demand of the grid circuit of the modulated amplifier. From the final amplifier the signal passes through the vestigial-sideband filter to the combining unit, where the sound and vision signals meet for the first time; mated, they pass together through the aerial switching unit, whence they are routed up the tower to the selected half-aerial and so into space.

The Sound Transmitters

Designed for a radiated carrier power of 3¾ kW, each sound transmitter faces its vision counterpart across the main transmitter hall; the fractional output arises because of the need to maintain the preferred 4 : 1 ratio between the vision and sound signals. The r.f. unit has three stages: input from the driving source is at 5 watts at the radiated frequency of 41·5 Mc/s; a double-tetrode in push-pull supplies 40 watts to the penultimate amplifier, whose pair of push-pull tetrodes deliver 700 watts to the final, modulator, amplifier. Anode modulation is used; the BR191 triodes have earthed cathodes and are connected in push-pull with conventional bridge neutralizing.

Into Service

Full technical details of the station, the transmitters, the aerials and the link between Crystal Palace and Broadcasting House were given in a trio of papers read before The Institution on the 4th April, 1956, a few days after the service transferred officially from its old home. For, on the 27th March, in a mood that was understandably nostalgic, Alexandra Palace went into honourable retirement after 20 years, and on the following day the lusty infant of Sydenham Hill shouldered the burden of daily service. But very much an infant, for Crystal Palace was, and still is, incomplete, since it will not be able to radiate its full 200 kW until the end of 1957; indeed transmissions have commenced with less than a third of this power, because the new tower cannot yet be brought into use and must be deputized for by a temporary 250 ft stripling.

The Television Advisory Committee, having consulted the radio industry and discussed the matter fully, has decided that it is in the general interest to radiate both the B.B.C. and the I.T.A. signals from the Crystal Palace tower. A site for the I.T.A. building exists immediately adjacent to the B.B.C. building, and the B.B.C. has made available on its tower space for the I.T.A. aerials. However, the transfer of the commercial service from its present site at Beulah Hill—about a mile from the Crystal Palace—will probably be delayed by more urgent work which the I.T.A. has on hand in other parts of the country.

However, now that Crystal Palace has been operating for several weeks, it is possible to see how far it fulfils its promise. So far as the B.B.C., the operators, are concerned, it is essentially satisfactory; occasions have arisen when it has become necessary to use the transmitter switching arrangements and these have worked so well that the great majority of viewers were unaware of the change. When the three papers describing the station were read before The Institution, the distinguished audience was given a truly international sparkle by the presence of members of the C.C.I.R. Study Group 11 who were at that time meeting in London to discuss colour television. Although their interests were naturally biased towards the colour aspects, these experts were loud in their praise of the design features of the station and its equipment, foreseeing for it a future even more glorious than that of its predecessor.

But in the final analysis it is the viewers who are the arbiters. For months before the change-over the B.B.C. radiated programmes instructing them in the changes which they might need in their receivers, especially in the two areas likely to experience the greatest differences—Muswell Hill and Sydenham; for viewers in the immediate vicinity of Alexandra Palace now need outdoor aerials for the first time, while many people in South London must discard theirs, and even fit attenuators to reduce the signal strength reaching the receiver.

From Kent, Surrey and Sussex the story is all favourable, with more than a million people now able to enjoy better reception than ever before. As so often happens with new projects, initial problems bring dissatisfaction to the few while the project as a whole confers benefits on the many; and there is no doubt that the discomfiture reported by viewers in a few parts of South London is but very temporary.

While a 405-line picture cannot, theoretically, have as much definition as one with a greater number of lines —assuming that adequate bandwidth is available— experience and world-wide opinion judge the B.B.C.'s pictures to be as good as, and in many cases better than, those produced elsewhere. This reputation was established at Alexandra Palace, long ago; the new station gives even better pictures, and will doubtless still further enhance the esteem in which British television is held throughout the world.

The three papers which provide a full technical description of Crystal Palace, and which give further insight into the philosophy of the design of the new station and its equipment, are soon to be published in the *Proceedings*. They are as follows:

McLEAN, F. C., THOMAS, A. N., and ROWDEN, R. A.: 'The Crystal Palace Television Transmitting Station', *Proceedings I.E.E.*, Paper No. 2069 R, March 1956 (**102** B).

COOPER, V. J., and MORCOM, W. J.: 'Band I Television-Transmitter Design, with particular reference to the Transmitters at Crystal Palace', *ibid.*, Paper No. 2075 R, March 1956 (**102** B).

RENDALL, A. R. A., and PADEL, S. H.: 'The Broadcasting House–Crystal Palace Television Link', *ibid.*, Paper No. 2072 R, March 1956 (**102** B).

SHORT REVIEWS OF PAPERS

Temperature Rises in Electrical Machines

A short review of three Utilization Section papers (Nos. 2026, 2031 and 2036) entitled (i) 'Temperature Rises in Electrical Machines as Related to the Properties of Thermal Networks', by J. J. Bates, Ph.D., Graduate, and Professor A. Tustin, M.Sc., Member; (ii) 'Temperature Rises in Electrical Machines on Variable Load and with Variable Speed', by Professor A. Tustin, M.Sc., Member, and J. J. Bates, Ph.D., Graduate; and (iii) 'Performance and Heating Curves for Motors on Short-Run Duties', by Professor A. Tustin, M.Sc., Member, D. F. Nettell, B.Sc., A.M.I.Mech.E., Associate Member, and R. Solt, B.Sc., A.M.I.Mech.E., Associate Member. The papers were published individually in April, 1956, and they will be republished in Part A of the Proceedings.

DESIGNERS OF ELECTRICAL MACHINES MAKE CONSTANT efforts to provide specified ratings with less material and lower cost, but the selection and operation of machines to meet the duty required of them most economically has received less attention, and appears to offer the possibility of important savings. For example, measurements were made recently in two steel works of the temperature rises of a large miscellaneous selection of motors at the end of a day's work. The temperature rises ranged from 5° C to 150° C, and it was noted that the higher temperatures usually occurred with totally enclosed motors from which the covers had already been removed to help matters. Most of the motors, however, had temperature rises below 40° C, though their insulation was Class B.

Sometimes there is good reason why a motor should be cool at the end of its normal day's work. It may have been selected to cater for some more onerous occasional condition, that did not happen to occur on the day of the observation, or it may have been selected for a required maximum torque, which is needed only for short periods, and which could not be given by a motor of lower rating, or a larger motor than necessary may have been used for the sake of standardization.

But the methods available for motor selection are such that one would expect waste and inconsistency. Users are practical men. They are guided by experience, assisted by simple calculations. Even if the information given by the manufacturer about the capabilities of the motor were logically adequate as a basis for choice (which it rarely is), the user can scarcely be expected to make a laborious investigation, by sophisticated methods, of every motor application. Of course, if a motor is required to run all day, on a known constant load, then the choice to ensure a safe temperature rise is easy. It is merely a matter of choosing a motor of adequate continuous rating. The difficulties arise with motors that work intermittently, at variable loads and with variable speeds.

A New Approach to Motor Selection

A new approach has been made to this problem of selecting motors for variable-speed short-run duties. Though only a first step, it proposes simple and adequate means for temperature estimation in that extensive class of application in which the duty consists of short runs, incident in an irregular manner, and in which the most onerous duty will be an irregular schedule of this sort sustained over considerable periods. Such duty occurs, for example, with cranes and urban traction. Then the mean temperature rises will reach values high enough to dissipate the mean losses. It is shown how the values of these mean temperature rises may be estimated very simply, by direct comparison with temperature measurements made on the test bed.

The actual temperatures of the windings, of course, vary about their means, rising during periods of high load and falling during periods of low load. But at, say, 500 amp/cm^2, assuming no dissipation, copper can heat up at the maximum rate of only 0·15° C per sec. The high-load periods are usually the periods of acceleration, which last for only a few seconds, and the variations about the mean temperature are usually negligible. Such variations may be estimated very simply and allowed for if necessary.

Potential Temperature Rise

A machine on varying duty passes through various operating conditions, in each of which definite rates of energy loss or heat inputs in the various parts occur. Often thermal conductances through which the heat is dissipated will change also, on account of the changing speed. This feature, if present, is left for correction later, and the conductances are taken to be constant and to be those corresponding to an arbitrarily chosen standard speed. When the losses are those of a particular operating condition, but the conductances those of the standard speed, the temperature rises that would ultimately result are called the 'potential temperature rises' of that operating condition.

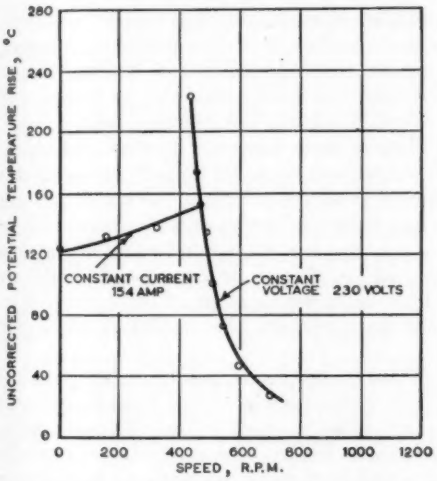
It is easily proved that, for varying losses but constant conductances, the mean temperature rises are equal to the time means of potential temperature rises for the various operating conditions.

The mean temperature rises that would occur if the thermal conductances are assumed constant (and equal

to those for the standard speed) are thus very easily calculated for any schedule of operating conditions, provided that the potential temperatures have been measured.

There remains the step of allowing for the fact that, in the required operation, the thermal conductances may vary because the speed varies. The speed is not the standard speed, except perhaps momentarily. The temperature rises are higher or lower according as the mean speed on the schedule is less or more than the standard speed, and, as a good approximation, it is shown that the correction required is a function only of the ratio of these speeds. It may, however, be necessary to make a special allowance for standstill periods if the proportion of standing time is large.

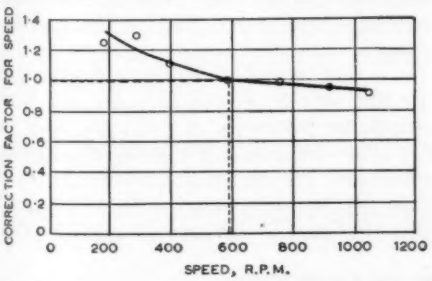
Thus the temperature rise, say of the armature winding



1 *Temperature characteristic curve for a 25 h.p. mill-type motor, forced ventilated*

Standard speed, 590 r.p.m. Standard temperature, 90° C.

or of any selected part, on any short-run service is immediately obtainable, if there is available for the motor in question one curve from which the potential temperature rises may be read for the various operating conditions, and another curve giving the correction factor



2 *Cooling correction curve for a 25 h.p. mill-type motor, forced ventilated*

Standard speed, 590 r.p.m.

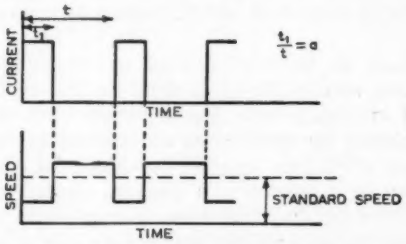
according to the ratio of the scheduled speed to the standard speed. These two curves adequately specify the capabilities of the motor for such duties.

Figs. 1 and 2 give examples of such curves obtained from test-bed measurements on a 25 h.p. forced-ventilated mill-type motor.

Test-Bed Measurements

The potential temperature rise as defined is the temperature rise that would ultimately be reached if the operating condition were maintained constant so far as losses are concerned, but the heat dissipation were that of the standard speed.

One cannot usually secure this condition by normal continuous operation, but one can easily secure it by intermittent on-off operation. Let the machine be operated as shown in Fig. 3. For a period t_1 (of a few



3 *Type of on-off loading required for the data runs*

minutes' duration) it works under the operating condition in question. The speed during this period will not normally be the standard speed. In the next short interval t_2 the machine is operated without load, and as far as possible without losses, but is rotated at a speed such that the mean speed over the cycle is the standard speed. This cycle is repeated until the mean temperature rises have settled down. The mean losses are then $t_1/(t_1 + t_2)$ of the losses in the operating condition, and the speed is the standard speed. If the mean temperature rise measured is θ_m, the potential temperature rise is by definition $\theta_m(t_1 + t_2)/t_1 = \theta_p$.

Similarly the correction for speed may be obtained experimentally by keeping the operating condition during the 'on' period constant, and giving the mean speed various values by varying the speed during the 'off' period over a wide range.

The proposal just described may be regarded as a variant on the well-known method of specifying the capabilities of a motor by the ratio of 'on' to 'off' period that will result in some specified temperature rise not being exceeded on a continued on-off test. The same kind of testing is proposed, but the data are to be obtained under conditions in which the mean speed is controlled. The potential temperature rise, as the expression of the result of an on-off test, has the practical convenience that the mean temperature rise on any schedule is obtained by averaging the potential temperature rises for the operating conditions that occur, weighted according to the proportion of the total time for which each operating condition lasts. The result is corrected for mean speed, if necessary, as a final step.

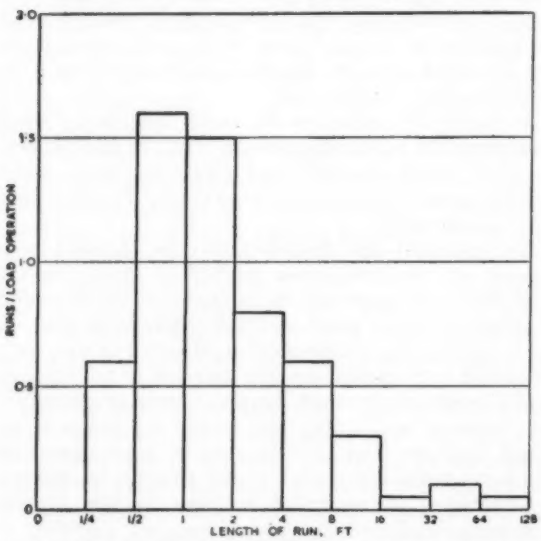
Statistically Specified Operations

There are many duties in which it is impossible to predict in detail the operations that will constitute the most onerous duty. All that one can predict is of a statistical nature. For example, in servo systems, while it is never possible to predict the movement actually to be given to the load, it is possible to say that the most onerous duty will involve operation over certain combinations of torque and speed, and to specify the relative proportion of the total time that operation will be within some specified small range approximating to each possible combination of torque and speed, i.e. to a particular 'operating condition'.

In all such instances the mean temperature rise, say of the armature winding, is immediately given by averaging the potential temperature rises for the various operating conditions, allowing for the probable relative time at or near each operating condition, and correcting for mean speed.

For duties such as those of motors on workshop cranes one cannot specify the exact sequence and time of incidence of individual runs, but the most onerous duty may adequately be specified as the making of so many runs, each of various lengths, per hour. Such a requirement may be expressed in a diagram similar to Fig. 4, which shows the duty found by observation on a steel-works crane. In work of this nature each run of a given length involves momentary operation under a variety of operating conditions. One has the problem of estimating the mean potential temperature for all the runs, $\frac{1}{T_q}\int_0^{T_q}\theta_p dt$.

A further step towards speedy estimation of the temperature rise of a given motor on any such duty consists in calculating, once and for all, the value of $\int\theta_p dt = H$ for runs of various lengths. Given a curve of this 'heating value' H as a function of length of run, the calculation of the temperature rise for any combination of runs per hour of various lengths in various proportions becomes extremely easy. The possibility of producing such curves giving the heating values of runs of various lengths is one of the objects of study. Consideration of the shape or form of speed/time and current/time curves on stopping services is involved, and it is shown how curves giving heating-values and other characteristic curves may be produced by making use of principles of similarity.



4 *Number of runs made per load operation having lengths within various ranges*

Values recorded in service on a crane handling ingots.

Affine Characteristics

The authors have established the fact that if the magnetization curves of a variety of motors are the same shape, their speed/current, speed/torque and current/torque characteristics will also be of the same shapes, irrespective of size, e.m.f. and windings. The relative resistive e.m.f. in the motor circuit must, however, also be unchanged, and separate shapes will result for various values of this factor. By extension of the principle, the conditions are found under which the 'run' curves (including current-time curves) are of the same shape. Certain further parameters must be specified for this to be the case, and distinct shapes occur for each combination of such parameters. Fig. 5 shows how various characteristic curves are related.

By a set of curves of given shape is meant that the curves of the set differ only in one or both co-ordinate scales. They are *affine* to each other, this term being used in preference to *similar*, because the latter is usually taken to mean that both scales are changed in the same ratio.

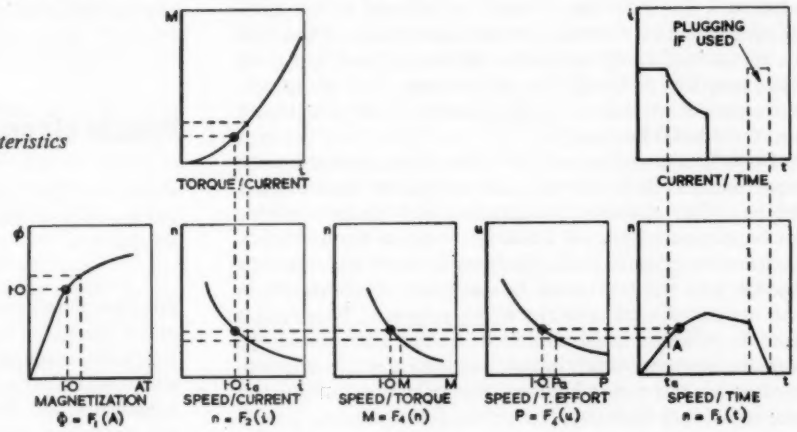
The heating effect, $\theta_p dt$, for each of an affine set of current/time curves would be given by plotting the corresponding values of θ_p for all of them, and measuring the areas under the curves so obtained. These values may be obtained by making the calculation for any one of the curves, and multiplying the result by appropriate scale factors. There is a scale factor for time, and a scale factor for relative temperature, the latter being related to the continuous rating of the motor under consideration.

The final outcome is that curves may be drawn giving the heating value of runs of various lengths, each curve being valid for a wide range of motors and operating conditions. In this way a substantial stage has been traversed towards the possibility of providing data on the capabilities of motors such as will provide users with rapid, convenient and sufficiently accurate estimates of the temperature rise to be expected on variable-speed short-run duties that may be specified only statistically.

Further Needs and Future Studies

Attention must be called to the fact that the discussion in these papers of the heating of machines is limited to

operations in which periods of high or low load are relatively short compared with the thermal time-constants of the windings, but in which the average rate of working over longer periods is constant. It is only under these circumstances that the thermal capacitances play a minor part, and the possibility exists of obtaining the mean comparable in duration with the time-constants can occur on gradients, or through exceptional duties such as pushing another train, but in which a maximum duration can be set to such duties. The thermal capacitances contribute to meeting such periods of overload, and cannot be neglected.



5 *Relationship between various characteristics for the model motor*
○ Representative point.

temperature rises by comparison with test-bed measurements that are of the nature of continuous tests.

This approach may be adequate, for example, when dealing with urban electric-traction services with frequent stops. But there are instances in which the rate of working is high for a time (say, on the frequent-stop part of a route) and much lower for intervening periods (long suburban runs with perhaps long lay-overs). In such cases the motor heats up during the period of more intensive duty and cools down during the rest of the time. The thermal capacitances are then essentially involved.

A similar situation generally exists on main-line electric traction, where periods of extra-heavy duty

Further work is in progress which aims at providing the simplest means for estimating the maximum temperatures under such circumstances by direct reference to data obtained on the test bed.

Another need, not met by these papers, is a simple means of choosing a motor, taking account not only of the need to avoid excessive temperature rise, but to secure a most advantageous balance between first cost and operating cost. A basis has been provided for deriving guiding rules for the selection and mode of operation of motors on specified types of service, because the generalized motor characteristics described by the authors will give a starting point for such studies. This work is also proceeding. 621.313.13.017.7

Papers read at the Convention on Digital-Computer Techniques, April 1956

The remainder of the short reviews published this month is a first selection of reviews of papers read at the Convention on Digital-Computer Techniques, which was held by The Institution from the 9th to 14th April, 1956. The papers reviewed here were all read at General Sessions of the Convention. Further selections of reviews of Digital-Computer papers, including those read at the Specialist Sessions, will be published in future issues. The complete papers will be published in a special supplement to the *Proceedings*, as announced in the July *Journal*, p. 446.

A Load-flow Problem

Paper No. 1957 entitled 'Digital Computers and the Load-Flow Problem', by J. M. Bennett, Ph.D., Associate Member.

THE AUTHOR DESCRIBES A TECHNIQUE FOR HANDLING ONE of the problems encountered by power engineers. It is a problem suitable for solution by automatic digital computers, and is that of determining the phase angles and amplitudes of currents and voltages in a passive electrical network when the powers supplied to and extracted from the nodes of the network (busbars) are given. The particular form of the problem, to which examples in the paper are restricted, is that in which one busbar (the reference busbar) is maintained at a fixed voltage, and all system losses are supplied through it. Moreover, all loops are closed, in the sense that the product of the

vector transformation ratios around any loop, taken in a common direction, is unity. Line capacitances are ignored. Removal of these restrictions presents no special difficulty; the mathematical techniques which would be employed have been developed elsewhere.

The work was carried out on the digital computer at Manchester University. The drum-backing store associated with this machine makes it well suited to this class of problem. This drum is designed to retain 16000 words in all, each of 40 binary digits, thereby providing a store adequate for retaining the programme and numerical information necessary for the solution of networks with more than 100 busbars.

Initially, the voltages at all busbars are assumed to be equal to, and in phase with, the voltage at the reference busbar. This enables an approximation to the currents to be computed for all busbars. From a knowledge of these currents, potential differences between the reference busbar and the individual busbars can be computed in the manner described in the next paragraph. These p.d.'s lead to a better approximation to the currents at the various busbars, which in turn leads to a better approximation to the p.d.'s between the reference busbar and the individual busbars. The process is continued until it has converged far enough.

The relation between currents injected at the busbars and p.d.'s between the reference busbar and the individual busbars is obtained by setting up the admittance matrix according to Kirchoff's laws. The resulting set of simultaneous linear equations is solved to obtain the p.d.'s as unknowns.

In practice the equations are not solved explicitly at each step of the iteration. Most of the reduction process carried out on the admittance matrix itself can be done once and for all for any one configuration of the network, and stored for use when a solution is required for any set of currents at the busbars.

The programme has been arranged so that it is valid for any number of busbars and connecting lines up to the limit set by the available storage space. It enables the machine to set up the admittance matrix from a list of the impedances of the connecting lines, and also a connection matrix, the elements of which are 0, +1 and −1, which describe the interconnections of the network in a form acceptable to the machine. The technique used is that first proposed by Gabriel Kron. All calculations are checked, either by repetition or by the use of row and sum checks.

An example with 48 connecting lines and 24 busbars was solved in just under an hour. This time was taken up as follows:

	min	sec
Input of impedances and loads	1	10
Input of connection matrix	0	45
Setting up of admittance matrix	13	0
Reduction of admittance matrix	13	20
Four iterations for the given set of loads ..	24	40
Output of busbar currents and voltages ..	2	0
Total	54	55

These times include the times for checking. When the programme was constructed emphasis was placed throughout on ease of programming; by the use of different programming techniques, it should be possible to cut this time to about 20 minutes. It is worth mentioning in this connection that digital machines are now becoming available which are capable of completing a calculation of this size in several minutes.

621.374.32 : 681.142 : 621.316.1

Synchrotron Calculations

Paper No. 2032 entitled 'The Use of the Pilot Ace for Testing a New Design of Proton Synchrotron', by G. G. Alway, B.A.

THE NEW PROTRON SYNCHROTRON BEING BUILT AT GENEVA under the auspices of the European Council for Nuclear Research employs a new magnetic focusing principle, which was discovered by Christophilos and by Courant, Livingston and Snyder.* This enables the amplitudes of the free and forced oscillations of the accelerating particles to be decreased, so that the vacuum-chamber size, and hence the size and cost of the magnets, can be reduced. Thus the energies of the particles produced by the new machine will be about three times those of an old-style machine of equivalent cost. The new principle increases the frequency of the betatron oscillations by alternating the sign of the gradient of the magnetic field. A number of magnetic sections are employed which focus alternately in two perpendicular directions, and an overall focusing effect in all directions is achieved. Some of the calculations of the efficiency of this arrangement have been made using the Pilot Ace. They have been concerned with the magnitude of the oscillations due to the inevitable magnet misalignments and heterogeneities occurring in any actual machine. The paper is concerned with numerical evaluation of incomplete elliptic integrals of the first kind and associated integrals, which occur in the solution of the differential equations representing the motion of the protons. 621.384.612 : 518.5 : 681.142

Traction Problems

Paper No. 2113 entitled 'The Application of Digital Computers to Electric Traction Problems', by A. Gilmour, M.A.

TRACTION PERFORMANCE CALCULATIONS ARE MADE BY most railway companies and manufacturers to determine the most suitable form of equipment for carrying out a certain task. The calculations involve the solution of the equations of motion of the train, given the speed/power

* COURANT, E. D., LIVINGSTON, M. S., and SNYDER, H. S.: 'The Strong-Focusing Synchrotron—A New High Energy Accelerator', *Physical Review*, 1952, **88**, p. 1190.

characteristics of the locomotive, the resistance to motion of the train, the position of stations and speed restrictions, and the topography of the route. For electric traction it is usually necessary to calculate energy consumption and r.m.s. current in order to obtain a measure of motor heating.

These calculations are extremely laborious when performed by hand, a typical calculation for 200 miles of track taking about 40 man hours. By using a digital computer this time can be reduced to between ten and twenty minutes.

The programme for carrying out these calculations is described in this paper and is made up of three main parts. In the first part the machine computes gradient and curve resistance, and punches this data out in binary form, together with the positions of stations and speed restrictions. In the second part the computer fits algebraic polynomials to the speed/power characteristics of the locomotive and the resistance of the rolling stock. In the last part of the programme the speed/timing calculation is performed using the data obtained in the first two parts. The equations of motion are solved by a step-by-step method, and one of the most interesting features of the programme is that at each step the machine tests whether the brakes should be applied in order to obey the next speed restriction.

This programme is described in considerable detail in the paper, so that traction engineers may understand the way in which a typical calculation is performed on a digital computer. Other applications briefly mentioned are the calculation of substation loading curves, fuel economy studies, the design of overhead structures and bridges and the study of rectifier harmonics.

621.33 : 681.142

Electric Switching Operations

Paper No. 2120 entitled 'The Use of Digital Computers in obtaining Solutions to Electric-Circuit Problems involving Switching Operations', by S. J. M. Denison, B.A., and D. G. Taylor, B.Sc.(Eng.), Graduate.

A BRIEF ACCOUNT IS GIVEN OF THE ANALYSIS OF ELECTRIC circuits by matrix methods as a means of obtaining differential equations relating the electric quantities in a circuit to the impedance properties of the circuit. Reference is made to a Deuce programme, by means of which many switching problems can be solved, using a step-by-step method. For a problem involving one switching operation the procedure is to establish the equations for the circuit configuration after the switching and to solve these equations from known initial conditions. A problem involving a number of sequential switching operations can be dealt with as a series of single-switching problems, the final conditions for one problem providing the initial conditions for the subsequent problem. This procedure is tedious, however, if the number of switching operations is large, as is the case with rectifier problems.

The bulk of established rectifier theory is based on the assumption that the rectifier output current is perfectly smoothed. This assumption is quite unacceptable for many problems and the possession of high-speed computing facilities makes possible a more realistic approach.

In simple rectifier circuits for which there is a large demand for solutions it has been found desirable to make a special programme for each type. For a given type of circuit, sets of equations for all possible configurations are stored, the set appropriate to the configuration is selected and solved and the solution examined to detect an ignition or an extinction. Two such programmes have been made. The first is for calculating fault conditions subsequent to a backfire in a 3-phase rectifier. The second programme deals with normal operating conditions of 2-phase (or single-phase bridge-connected) rectifiers. Both programmes have facilities for taking account of grid-control. The 2-phase programme has been used extensively in calculating harmonics in the input and output currents of traction installations, which are of topical interest in connection with the future electrification of British Railways. Steady-state solutions were analysed into harmonic components using an existing programme.

The techniques employed in making the special programme are unsuitable for more complicated rectifier circuits. Furthermore there are many circuits which are of interest but for which the demand for solutions would be insufficient to justify the making of special programmes. A description is given of a method which will form the basis of a general rectifier programme.

The extensive use which has been made of the special programmes has indicated the value of these facilities for providing solutions at short notice over a long period of time. It is anticipated that the existence of a general programme will make worth while the solving of problems which occur too infrequently to justify the making of special programmes and which otherwise would not be tackled with so much rigour.

621.316.5 : 681.142

Automatic Sorting

Paper No. 2014 entitled 'Sorting of Data on an Electronic Computer', by D. W. Davies, B.Sc.

MUCH OF THE WORK DONE BY CLERKS IS SIMPLY A MATTER of processing data according to fixed rules, and a certain sector of this work has been mechanized for many years by punched-card machines. One of the processes carried out very efficiently on punched cards is *sorting*, which usually means the putting into sequence of a set of items of data according to the numerical order of a part of the items called the *key*.

A second stage in the mechanization of clerical work

is now in progress, namely the use of electronic general-purpose digital computers. These promise great economies, chiefly because very complicated rules for processing the data can be mechanized, thus eliminating human control almost entirely.

The punched-card sorter works in only one way, but electronic computers can carry out any sorting process that can be devised. Many sorting processes are described in the paper. The data to be sorted are usually too great to be stored inside the computer, and they are held externally on an input-output medium, on which they are accessible only in a certain sequence. An ideal medium for this purpose is magnetic tape. Sorting methods are described in the paper in terms of a machine with several magnetic-tape units—a minimum of three or four according to the method.

Different methods are found to be advisable in different cases. The features of sorting problems which determine the best sorting method are:

(i) Existence of many items with the same key.
(ii) The need to preserve the existing order among items with the same key.
(iii) The way in which the keys are distributed. Suppose the key is a 6-digit number. If all the million items 000 000 to 999 999 are present, there are many efficient sorting methods. If a smaller number of items is to be sorted, say 10 000, and these have keys which are fairly uniformly spread over the range 000 000 to 999 999, the efficient sorting methods are fewer. If the 10 000 items are badly distributed, there is even less choice of method. A common example of a bad distribution occurs when the key is a person's name. Nevertheless, there are sorting methods for all cases.
(iv) The knowledge of some degree of ordering already existing before the sorting is started.

In spite of the variety of sorting methods available, it is desirable to avoid sorting on electronic computers if possible. This contrasts with punched-card machines, where sorting is often introduced to increase the speed of a process. The reason is that the punched-card sorter is the fastest punched-card machine, whereas sorting on an electronic computer is usually limited by the speed of the input-output mechanism. 621.374.32 : 681.142

Exploration of Functional Relationships

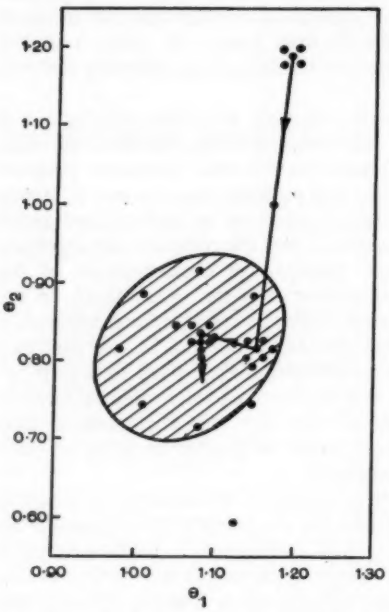
Paper No. 2138 entitled 'Application of Digital Computers in the Exploration of Functional Relationships', by G. E. P. Box, B.E.M., B.Sc., Ph.D., and G. A. Coutie, M.A.

IN ORDER TO DISCOVER THE OPTIMUM PROCESS CONDITIONS and to supply basic data for process control it is necessary to determine, at least approximately, the process law:

$$\eta = f(\xi_1 \ldots\ldots \xi_k;\ \theta_1 \ldots\ldots \theta_p) \quad . \quad . \quad (1)$$

connecting a response η, such as yield of product, with levels of the variables $\xi_1 \ldots\ldots \xi_k$, such as temperature, time, pressure, etc., and with unknown parameters $\theta_1 \ldots\ldots \theta_p$.

The problem is discussed of using an electronic digital computer for fitting the function (1) to a set of observed data (*a*) when the functional form is unknown but can be locally represented by a multivariate polynomial, and



Course of the least-squares calculation to determine (θ_1, θ_2)

(*b*) when the functional form is not known explicitly, but is thought to be the solution of *s* simultaneous differential equations.

In (*a*) the electronic computer is used in solving the normal equations which result from fitting the multivariate polynomial by least squares, determining the standard errors of the coefficients and analysing the fitted equation.

In (*b*), starting with any guessed values of the parameters $\theta_1 \ldots\ldots \theta_p$, the computer is caused to follow a series of trial values which result in smaller and smaller discrepancies between observed and calculated values of η. The procedure provides the least-squares estimates of the parameters and their standard errors; it also gives a criterion from which the adequacy of the form of the assumed sets of differential equations may be judged.

An example of the application of the method is described. In this, from six duplicate observations showing the progress of a chemical reaction, the representational adequacy of a postulated set of differential equations derived from chemical theory is confirmed, and estimates of the rate-determining constants and their standard errors are obtained. The Figure shows the course of this calculation, where θ_1 and θ_2 are unknown constants to be determined, and the points

represent trial values. The calculation proceeds from guessed values of θ_1 and θ_2 (1·19 and 1·19) to the final values (1·072 and 0·819). The limit of error of the estimates is represented by the shaded region. 518.5:681.142

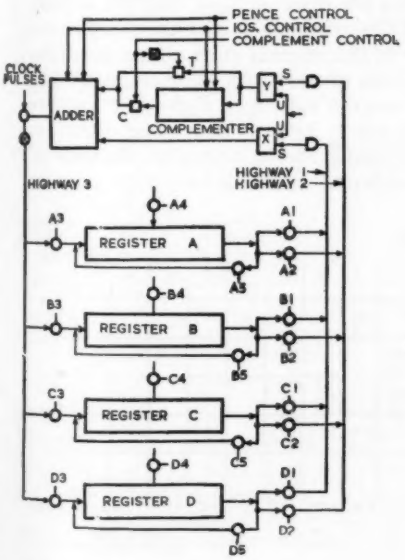
Electronic Accountancy

Paper No. 1867 entitled 'An Electronic Calculator for Punched-Card Accountancy', by L. Knight, Associate Member.

THE PAPER DESCRIBES A COMMERCIALLY PRODUCED calculator which will read numbers off a punched card, calculate new information from these and punch the answers back into the same card, handling 100 cards per minute.

The basic storage device within the calculator is a double triode connected in a trigger circuit so that it has two distinct stable states, called *on* and *off*. Four such circuits having significances of 1, 2, 4 and 8 respectively are used to store one decimal digit, the value of that digit being given by the total value of the trigger circuits which are in the *on* state. Ten such groups of four are coupled together to form a register capable of holding a 10-digit number which may be in either decimal or £ s. d. notation.

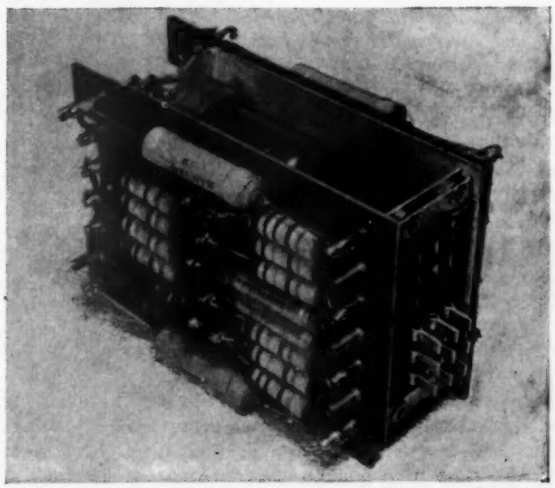
The layout of the basic arithmetic unit is shown in Fig. 1. Each of the four registers contains selenium diode gates which are arranged so that the receipt of one shift pulse (applied through gate A4, B4, C4 or D4) causes each digit to move one position to the right. Thus when a stream of ten pulses is applied the number moves completely out of the right-hand end of the register. The



1 *Basic arithmetic unit*

gates A1, A2, B1, B2, etc., then allow the number to be directed, digit by digit, onto either highway 1 or highway 2. By means of the gates A3, B3, etc., other digits can be injected into the left-hand end of the register to replace the original ones.

Addition is achieved by feeding two numbers out simultaneously onto two different highways. The adder takes one digit of each at a time, one arriving through buffer X from highway 1 and the other through buffer Y and gate T from highway 2. From these it computes a sum digit and feeds this out to highway 3, from where it can be directed into any of the registers. Any quantity



2 *Typical 2-valve unit or turret*

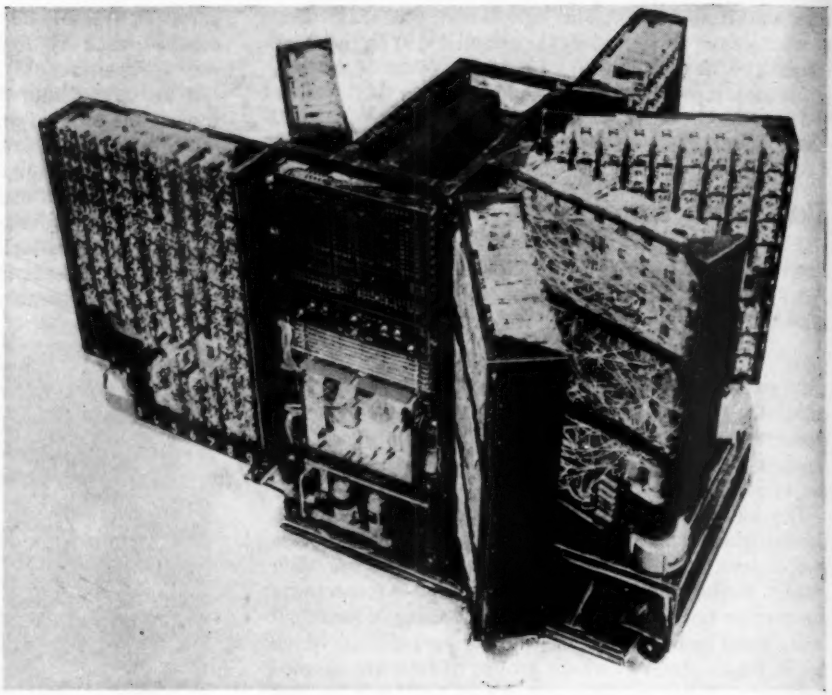
The valve holder is positioned so that it is easily accessible for measurement when the turret is in position. The 18-way connector can be hinged down to permit access to the tags at the back.

to be carried is remembered within the adder and added to the next pair of incoming digits.

When dealing with numbers in £ s. d. notation, suitably timed signals are applied to the pence and tens-of-shillings control lines to convert the adder to scale-of-twelve operation for the addition of the pence digits and to scale-of-two operation for the tens-of-shillings digits. Subtraction is achieved by raising the potential of the complement control line, thus closing gate T and opening C. The number from highway 2 is then converted into its complement and the result of adding this is the same as subtracting the original number.

The calculator has a plugboard which allows a sequence of up to 36 operations to be selected, the opening and closing of the correct gates in the calculation being controlled by special circuits connected to the plugboard. Special sequences such as multiplication and division are carried out automatically from simple instructions.

The calculator is built of 2-valve units, or *turrets*, such as that illustrated in Fig. 2 and the manner in which these fit into the main frame can be seen from Fig. 3.



3 *Calculator with gates opened and cover plates removed to show turrets*

At the top front is the display panel which shows by means of neon lamps the contents of each register and the state of each important gate. Beneath are switches for servicing purposes, several panels containing diodes, the plugboard and, at the bottom, one of the power supplies. At the bottom of each gate is a cooling fan.

In the design special attention has been paid to achieving reliable operation and simplifying servicing. Facilities have also been included for checking that the correct answers have been punched. 621.374.32 : 681.142 : 657

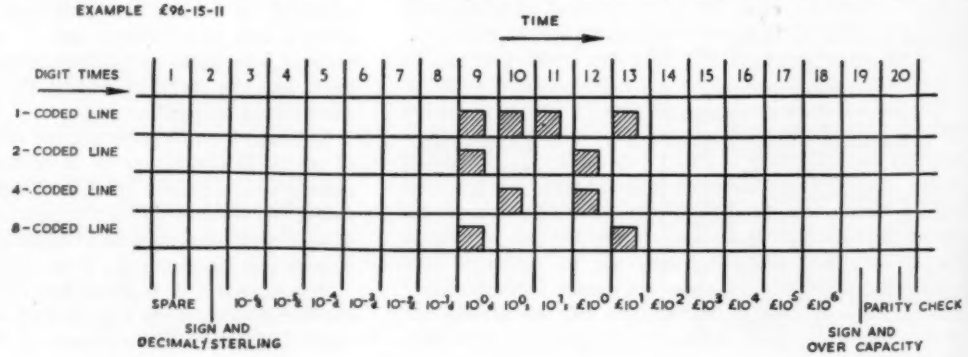
The Programme-Controlled Computer

Paper No. 2063 with the above title by E. J. Guttridge and R. P. B. Yandell, B.Sc.

THE PROGRAMME-CONTROLLED COMPUTER (P.C.C.) HAS been designed to satisfy commercial requirements. It is not a universal computer in the sense that it replaces all other existing punched-card machines, but is a useful addition to the range of these machines, and is used in conjunction with them. The main use of this computer will be in stores control, bonus and pay-roll calculations, public-utility billing, invoicing, etc.

It is programmed by inserting four printed connection boards before a computation is commenced. The instructions are represented on the boards by connecting rivets. For the special purposes of the P.C.C. this arrangement has important advantages, and the control is designed so that the method has few disadvantages over the normal method of storing the instructions with the numbers to be operated upon in the internal store of the machine.

The P.C.C. operates directly with numbers in sterling or decimal form, and the individual digits of a number are represented in the 1, 2, 4, 8, code. The digits are transferred serially, whilst the binary-coded elements of each digit are transferred in parallel on four lines as

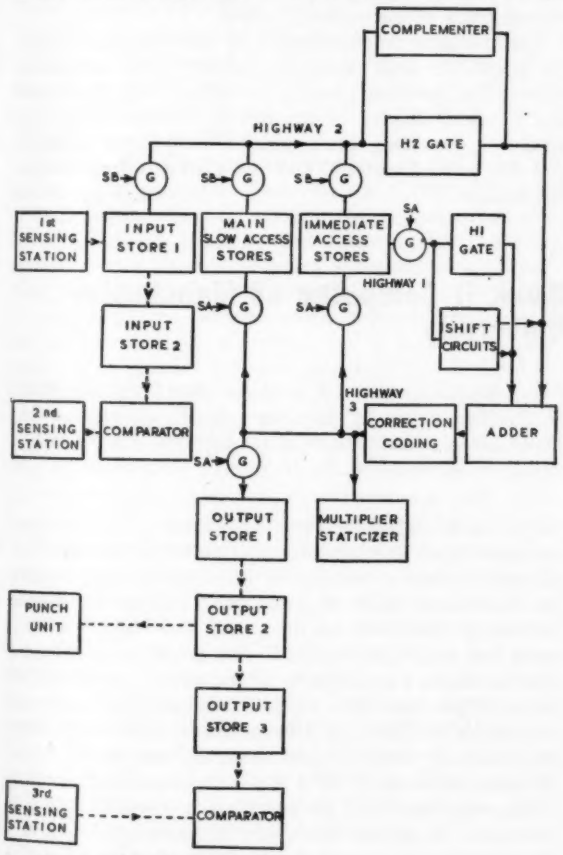


1 *One word represented on four lines*

shown in Fig. 1. Numbers are stored on a magnetic drum in a similar manner, the binary-coded elements occupying four separate tracks. Immediate-access storage and slow-access storage are provided on the drum. Immediate access is obtained by using the drum as a delay line, and feeding back from the 'read' head to the 'write' head, these heads being displaced by the correct distance to accommodate one number. The main storage is of the slow-access type. Forty numbers are accommodated on each set of four tracks around the drum, only one of these numbers being available to the computer at a given time.

The main components of the P.C.C., excluding the programme control, are shown in Fig. 2. Input and output are by means of punched cards, plugboards giving the necessary flexibility of card layout. It will be seen that there are three sensing stations where the cards are read, and one punching station where computed results are punched into the cards. Cards visit each station in turn from top to bottom of the Figure, four cards normally being in the machine at any given time. Only the input information from the last card to be read at the first sensing station is used for computation. The other sensing stations are for checking input and output in co-operation with input store 2 and output store 3. The results to be punched into the card are assembled in output store 1 during a programme and are then automatically passed to output store 2, which controls the punching operation. The maximum card speed is 120 cards per minute, and the majority of commercial jobs can be performed at this speed. If longer computation time is necessary, the P.C.C. automatically takes extra machine cycles.

621.374.32 : 681.142



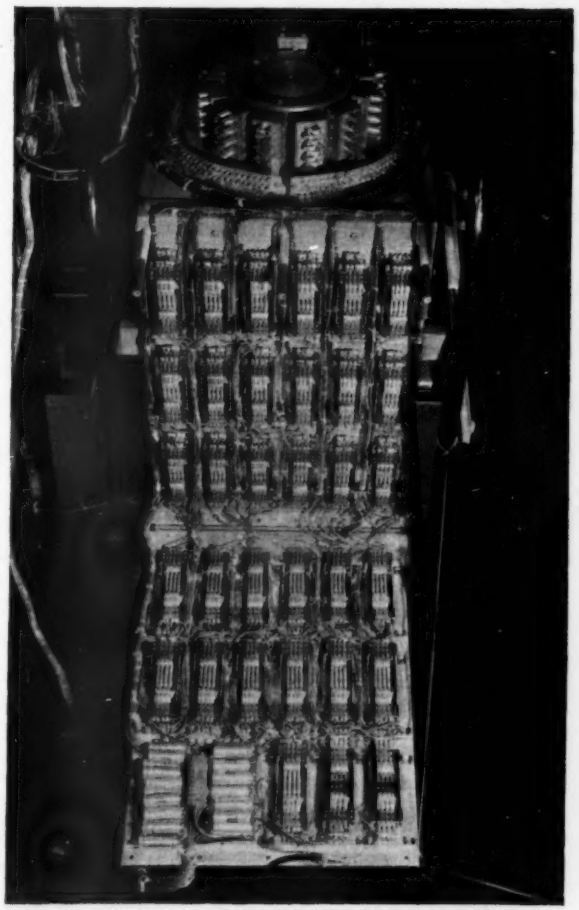
2 *Stores and arithmetical unit*

---- Automatic transfers.
—— Programme-controlled transfers.

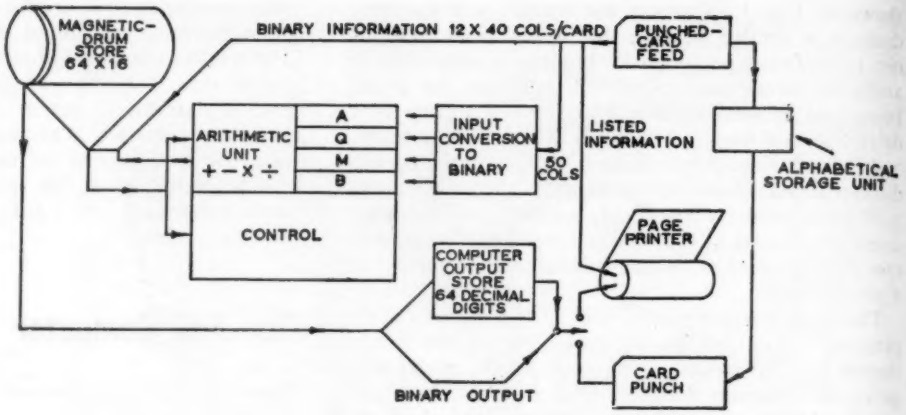
The HEC Computer

Paper No. 2052 with the above title by R. Bird, M.Sc.(Eng.).

EVOLVED FROM THE HEC2M COMPUTER, WHICH WAS primarily a machine for the scientific field, the HEC4E computer is intended for commercial use, and the input and output arrangements have been greatly extended.



1 *The magnetic drum store of the HEC4E computer*



2 *The units of the HEC4E computer*

In general, the commercial use of computers demands a shorter length of calculation performed on each group of input numbers and an increased volume of input information over that required for scientific use. The majority of scientific data for calculation is in decimal form, while for commercial applications often more than half of the input numbers are in other scales, such as sterling and avoirdupois. The HEC4E computer is therefore provided with input facilities for the conversion of the information on the punched card containing the calculation data to the binary scale of notation, while the card is being read. Output conversion of the binary results to other scales of notation is also provided; this is achieved by means of a special arithmetic function within the machine.

The HEC4E computing machine is an electronic digital machine of medium size functioning in the serial binary mode, the pulse repetition frequency being 40 kc/s and the word length 40 binary digits. The main storage for both numbers and instructions is a magnetic drum (Fig. 1) having 64 tracks, each holding 16 words.

For selecting the required information track on the drum surface, the 64 tracks are divided into groups of 32 even and 32 odd tracks, each group having an identical track-selection circuit of relays connected in a pyramid form. An electronic switch is provided between the outputs of the even and the odd relay track-selection circuits.

Number storage other than on the magnetic drum is provided (Fig. 2) by four 40-binary-digit shifting registers —the A- Q- M- and B-registers—one of which (the A register) has an adder-subtractor associated with it to form an accumulator. It is possible to read from the magnetic drum to all four registers, and to record the contents of the registers on the drum. As well as addition and subtraction, circuits are provided for automatic multiplication and division.

The input is by means of standard punched cards, and both a printing mechanism and a card punch are provided for the output of results. Up to 50 columns of non-binary information may be read off the input cards and converted to binary during one card-feeding cycle. For the input of instructions or data in binary form, 12 binary numbers, each of 40 digits, may be read from each card at a rate of 125 cards per minute.

To allow computation to continue while the output mechanism is printing or punching, a 64-digit output store is provided. The 64 digits are stored in the form of eight words, each of eight groups of four binary-coded digits on one track of the magnetic drum.

The machine is constructed in four physical units: the electronic unit, containing about 1 100 thermionic valves; the operating console, providing manual controls and a visual display of the course of calculation; the tabulator providing both punched-card input facilities and the printed output; and the card-punching output mechanism. 621.374.32 : 681.142

Mark II Computer at Manchester University

Paper No. 1926 entitled 'The Manchester University Mark II Digital Computing Machine', by T. Kilburn, D.Sc., Ph.D., M.A., Member, D. B. G. Edwards, Ph.D., M.Sc., and G. E. Thomas, Ph.D., M.Sc.

THE RAPID DEVELOPMENT OF DIGITAL COMPUTING MACHINES in recent years has been due mainly to the discovery of suitable storage systems. One of these systems, namely the cathode-ray-tube store, is used in the Manchester University Mark II machine, but provision has been made for rapid conversion to the newer magnetic-core type of store. The capacity of the main store is 10000 binary digits but this can be extended to a maximum capacity of 40000 digits. The main store has an operating frequency of 100 kc/s, and thus, by the provision of 10 separate channels, 10 digits become available in each 10 microsec period; this is called a *parallel mode of operation*. To pursue this mode of operation in the rest of the machine would be uneconomical and so the alternative method of transmitting digits sequentially in time along a single channel has been used. To avoid any

waste of the time gained by parallel operation of the main store the digit-repetition frequency in the rest of the machine has to be 1 Mc/s, i.e. 10 digits in 10 microsec. Thus at the output of the main store a parallel-to-serial conversion takes place, and at the input a serial-to-parallel conversion. Ideally the store can be regarded as operating serially at 1 Mc/s, direct operation of the store in this way being impossible at the present time owing to limitations of the storage systems.

The main store accommodates the data associated with the problem to be solved. These data consist in numbers on which computation is to be performed and instructions which specify exactly what operations the machine has to perform on the numbers. An instruction consists essentially of two parts—an address which specifies the location of a number in the main store and a function which determines the operation to be carried out. These operations can involve the use of either 10- or 40-digit numbers.

Addition, subtraction and various logical operations may be performed on two 10-digit numbers, one obtained from the main store and the other from one of eight 10-digit registers which are provided within the machine. These registers are also used as *B registers*, i.e. the contents of a selected register can be used to modify the address of an instruction as it is being obeyed. This process is convenient since it does not permanently modify the instruction and it involves no extra time in carrying out the modification.

The 40-digit numbers are expressed in the form $x2^y$ where x is a 30-digit number and y a 10-digit exponent, or scale factor, which defines the order of magnitude of x. In this way the machine can accommodate numbers expressed to a 30-digit accuracy anywhere in a number range extending over 1000 binary digits. This technique makes the machine simpler to use because it relieves the programmer almost completely of a major difficulty, namely scale factor. Computation carried out on numbers specified in this form is called *floating-point* arithmetic, and because the machine deals automatically with these numbers it is said to possess a *floating-point accumulator*. The operations of addition and subtraction on these numbers are carried out in 180 microsec, and multiplication followed by addition or subtraction in 360 microsec.

The machine's subsidiary registers, such as the 40-digit accumulator, the multiplier registers, and the eight 10-digit B registers, have been provided by the use of electromagnetic delay lines of the continuously wound type. Work has been carried out on these lines to reduce the variation of delay with temperature, and the final figure achieved is a 2% change in delay for a temperature variation of 100°C. The maximum length of delay line used before reamplification and retiming is equivalent to 10 sec, and the 0·2 microsec change in delay can be accommodated by the tolerance of the circuits used. The lines are constructed in unit lengths of 1 microsec delay, the physical dimensions being 6 inches length and approximately $\frac{3}{16}$ inch diameter. About 450 unit lengths are used in the machine.

In addition to the store which has been described, the machine will be provided with a magnetic-drum type store, which will extend the storage capacity of the machine to half a million binary digits. Input and output to the machine are at present by way of paper tape but the early use of magnetic tape is envisaged. Facilities for observing the content of the main store or any of the subsidiary stores are provided by cathode-ray-tube displays, a feature which is useful to both operator and engineer.

In conclusion it may be stated that the combination of parallel and serial techniques has proved particularly useful because it results in a high-speed economical machine. Indeed, compared with the earlier Mark I machine, the new machine is at least 10 times faster in operation and contains 17% less equipment, and power consumption has been reduced from 25 to 15 kW.

681.142 : 621.374.32

A Transistor Digital Computer

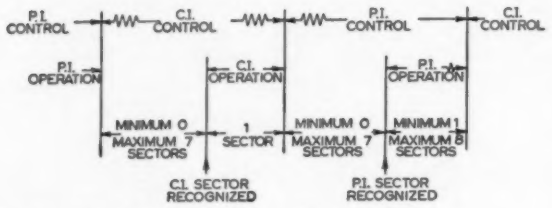
Paper No. 1964 with the above title, by E. H. Cooke-Yarborough, M.A., Associate Member, R. C. M. Barnes, B.Sc.(Eng.), Associate Member, J. Stephen, Ph.D., Graduate, and G. A. Howells, Associate Member.

A SMALL DIGITAL COMPUTER HAS BEEN CONSTRUCTED which contains no thermionic valves, the only active circuit elements being some 330 transistors, mostly of the point-contact type. Instructions and numerical data used in the computation are recorded on a rotating drum coated with magnetic iron oxide. The machine has an unusual feature which permits the reading of operands from addresses on the drum, the performance of an arithmetical operation and the writing of the result in another address on the drum to proceed concurrently so that very little storage external to the drum is needed. This concurrent operation is achieved by dividing the 64 words on each track of the drum into 8 sectors, each containing 8 words, and interleaving these words so that the first digits of all 8 words appear in succession, followed by the second digits of the same 8 words, and so on. Suitably timed reading waveforms allow any or all of the words in a sector to be read concurrently and to participate together in an arithmetical operation, or to participate with words selected from the corresponding sector of another track. Interleaving has the advantage of increasing the number of addresses available at any one time, e.g. by a factor of 8 with the present machine. The average time taken to reach information located at random on the drum is not reduced by interleaving; the effect is as if the number of tracks on the drum had been increased and the capacity of each reduced correspondingly.

Such short-term storage as is needed external to the drum is provided by registers consisting of 2-state circuits, each of which uses a single point-contact transistor. Voltages supplied by these registers control

germanium-diode gates which perform the necessary circuit switching. The 2-state circuit used has an extremely low output impedance and is able to control many diode gates.

The longest register (30 binary digits) is called the P.I. register and contains the instruction being executed. In arithmetical operations this instruction defines the operation to be performed and also the addresses of the two operands, of the result and of the next instruction. The address of the next instruction is stored in a shorter register called the C.I. The machine is controlled alternately by these two registers as shown in the Figure.



Time sequence of P.I. and C.I. control

The C.I. locates the sector containing the next instruction and feeds the instruction into the P.I., which then takes control and executes the instruction when the appropriate sector is reached.

Most of the normal operations expected of a large digital machine are performed by this computer, except division, which must be programmed. Interleaving permits some unusual operations to be performed, such as the addition of all 64 words on a single track in one operation, which is useful for checking the correctness of the contents of the track. Standard punched-card equipment is used for input and output.

The electronic circuits of the experimental machine are constructed on flat boards and cover a total area of about 30 ft^2 to a depth of about 1 inch. Much more compact construction is clearly possible, especially as heat dissipation presents no problem—the circuits consuming only 75 watts at a maximum voltage of 39 volts.

The machine is being equipped with a magnetic drum which will have an eventual capacity of more than 16 000 words. The smaller drum used during development has a capacity of only about 200 words, which precludes ambitious computations, but the machine is made to execute a self-checking test routine in which it generates pseudo-random numbers and operates on them. It ran in this way for most of every working day in the latter half of 1955. At the beginning of this period transistors failed at a rate of nearly 3 per week, but this fell as obsolete transistors were discarded to less than 1 per week at the end of the year. Owing to its open construction the machine is not immune from external interference, but error-free runs of several hours are frequently obtained.

621.374.32 : 621.314.7 : 681.142

Arithmetic Circuits

Paper No. 1992 entitled 'Transistor Arithmetic Circuits for an Interleaved-Digit Computer', by R. C. M. Barnes, B.Sc.(Eng.), Associate Member, G. A. Howells, Associate Member, and E. H. Cooke-Yarborough, M.A., Associate Member.

THE MOST IMPORTANT FEATURES OF THE ARITHMETIC circuits described are the use of transistors as the only active circuit elements and the design of the circuits to work with the interleaved-digit storage system described in accompanying papers.

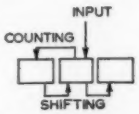
The logical design is based upon transistor bi-stable circuits controlling germanium-diode gates which perform the circuit switching. Each bi-stable circuit uses one point-contactor transistor and has a very low output impedance so that each circuit can control many gates. The circuit may be triggered into the conducting state by one or more diode gates. A more powerful pulse is required to turn off the bi-stable circuit, and the design of the computer is such that a mono-stable circuit generating a turn-off pulse may be common to as many as twelve bi-stable circuits. Transistor circuits and diode gates of a few standard types are used throughout the arithmetic circuits.

Because the binary digits of a number on the magnetic drum are interleaved with those of other numbers, two or more numbers can be read concurrently from one track. The digits of one number do not appear simultaneously with the corresponding digits of another number. The same applies to numbers read from different tracks unless they happen to occupy corresponding positions. The reading time is divided into major periods such that, during reading, the least significant digits of all the interleaved numbers occur in the first major period, the second digits in the second major period, and so on, until all 31 digits of each of the numbers have been read. The fact that digits of equal rank do not, in general, appear simultaneously has led to the adoption of a rather unorthodox adding circuit.

The Figure shows the sequence when two numbers 0110 and 0111 are added to form a sum 1101. During the first major period the least significant digits of the two numbers are selected from the output of the working store, and are shown in the Figure as inputs A and B. For the purpose of this example the adder is shown as two bi-stable circuits interconnected so that they can both count and shift, and a third bi-stable circuit which holds the output from the adder while waiting for the selected destination to become available. The counting circuit starts with contents 00 and counts the '1' digit from B during the first major period. At the end of this major period the contents of the adder are divided by 2 by shifting one place to the right and the remainder (a '1' digit in the present case) appears in the output stage. In the second major period the output digit, which is the first digit of the result, is written in the working

store and both inputs supply a '1' digit to the counting circuit. Its contents at the end of the major period are 10, and when shifted, the '0' appears at the output and the '1' is retained in the right-hand counting stage to be added to the digits occurring in the third major period. This process continues until all 31 digits of the words have been added.

Such an adder possesses several useful properties. Only 2 counting stages are needed in order to add 2



SEQUENCE	INPUTS		CONTENTS OF ADDER		OUTPUT
	A	B	MORE SIGNIF-ICANT STAGE	LESS SIGNIF-ICANT STAGE	
CLEAR	—	—	0	0	
1ST MAJOR PERIOD	0	1	0 0	0 1	
SHIFT			0	0	1
2ND MAJOR PERIOD	1	1	0 1	1 0	
SHIFT			0	1	0
3RD MAJOR PERIOD	1	1	1 1	0 1	
SHIFT			0	1	1
4TH MAJOR PERIOD	0	0	0 0	1 1	
SHIFT			0	0	1

Addition of two numbers

The adder is assumed to have two counting stages.

Example illustrated:

0110 A
0111 B
1101

numbers, but with 5 counting stages it is possible to add 8 interleaved words from one track and 8 from another track, 16 words in all, in one word time. The ability to add many words concurrently is used in multiplication, where 31 partial products must be added, each being the product of the multiplicand and one of the 31 digits of the multiplier. Multiplication proceeds in three steps, in which 11, 11 and 9 partial products are added, so that multiplication is completed in six word times. Where one of the numbers to be multiplied is only 11 digits long, multiplication can be completed in one word time and this facility is useful in decimal-to-binary conversion.

The arithmetic unit has been tested as part of the complete computer for several months. Marginal testing is used to detect incipient component failures by varying the potentials of critical supply lines. Test programmes, which operate with continuously varying digit patterns and which check the accuracy of the arithmetic unit have been used to eliminate pattern-sensitive faults.

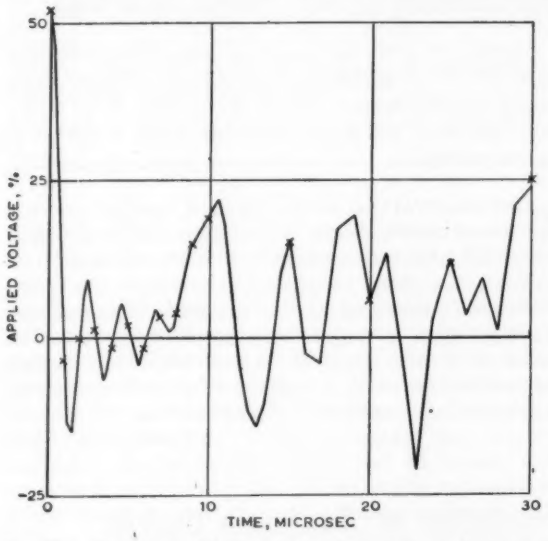
621.374.32 : 621.314.7 : 681.142

Design Problems

Paper No. 2092 entitled 'The Digital Computer as an Aid to the Electrical Design Engineer', by B. Birtwistle, B.Sc., and Miss B. M. Dent, M.Sc.

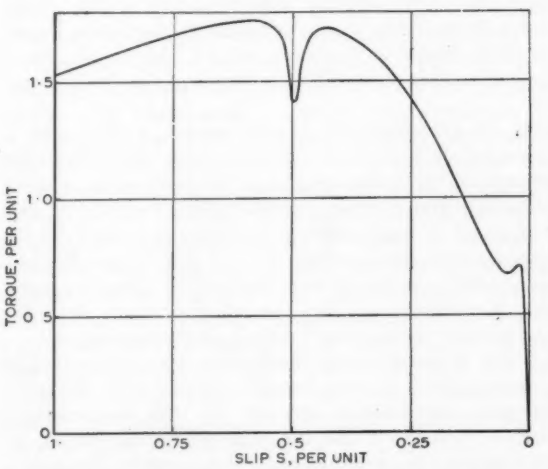
THE PAPER DESCRIBES THREE OF THE MORE RECENT problems that the authors have solved using the Manchester University computer.

The first problem is that of calculating the surge-voltage distribution in a transformer winding—a most important practical consideration. A complete curve



1 *Transformer problem: typical intersection-voltage curve (calculated)*

× Points calculated by Lewis's method.



2 *Starting-torque problem: torque/speed curve for motor with four damper bars*

(Fig. 1) takes about 5 hours of machine time, whereas the hand calculation of the 18 widely spaced check solutions using Lewis's method took some 3 man-months.

The second problem arose out of an investigation into the effect of supply-voltage ripple in a simple transductor circuit. The use of a computer enables a more realistic solution to be obtained, since it is a relatively easy matter to retain the practical non-linear magnetic characteristics in the calculation.

The third example describes the calculation of torque/speed curves for synchronous motors with damper windings, which are normally started under load with the damper windings used as a squirrel-cage starting winding. By using a digital computer one can obtain accurate and complete curves in about 15 minutes (Fig. 2).

These examples show that the high-speed digital computer can be a valuable aid to the electrical design engineer. 621.374.32 : 681.142

SYNOPSES OF PAPERS

Fluctuations in H.F. Radio Bearings

A synopsis of a Radio and Telecommunication Section paper (No. 2124) entitled 'Fluctuations in Continuous Radio Bearings at High Frequencies', by W. C. Bain, M.A., B.Sc., Ph.D. The paper was published in July, 1956, in Part B of the Proceedings.

BEARING OBSERVATIONS HAVE BEEN MADE WITH AN ADCOCK direction-finder on distant transmitters in the 3–4 Mc/s range, and the autocorrelation function of their time variation has been calculated. Curves of the form $\varepsilon^{-\tau/\tau_0}$ have been fitted to the functions obtained, the resulting values of τ_0 having a mean of 0·81 sec. The results differ from those in the 6–20 Mc/s band in that the standard deviation in a group of observations is not correlated significantly with the value of τ_0.

621.396.933.2 : 621.396.11

Prediction of Maximum Usable Frequencies

A synopsis of a Radio and Telecommunication Section paper (No. 2059) entitled 'The Prediction of Maximum Usable Frequencies for Radiocommunication over a Transequatorial Path', by G. McK. Allcock, M.Sc. The paper was published in July, 1956, in Part B of the Proceedings.

TIMES OF RECEPTION OF 15 MC/S RADIO WAVES OVER A transequatorial path of 7500 km have been recorded throughout the recent period of declining solar activity (1950–54). The analysis of these times has shown that predictions of maximum usable frequency made by the usual control-point method were, in general, too high by about 4 Mc/s, and at times by as much as 7 Mc/s or more. This is contrary to the normal experience for long transmission paths lying within a single hemisphere.

When a transmission mechanism involving multiple geometrical reflections is assumed instead of the forward-scattering mechanism implied by the control-point method, it is found that the path can be considered, for the purpose of predicting maximum usable frequencies, to consist of three reflections. The discrepancies between prediction and observation, which still remain after a three-reflection mechanism has been invoked, are attributed mainly to reflections from the sporadic-E region at the southernmost reflection point, although it is possible that lateral deviation of the radio waves is also a contributing factor. 621.396.11

An Electronic Relay

A synopsis of a Utilization Section paper (No. 2109) entitled 'An Electronic Over-Current Relay for Electrical Machines', by J. S. H. Goodall, Associate Member, and G. S. Chapman, Associate Member. The paper is published this month in Part A of the Proceedings.

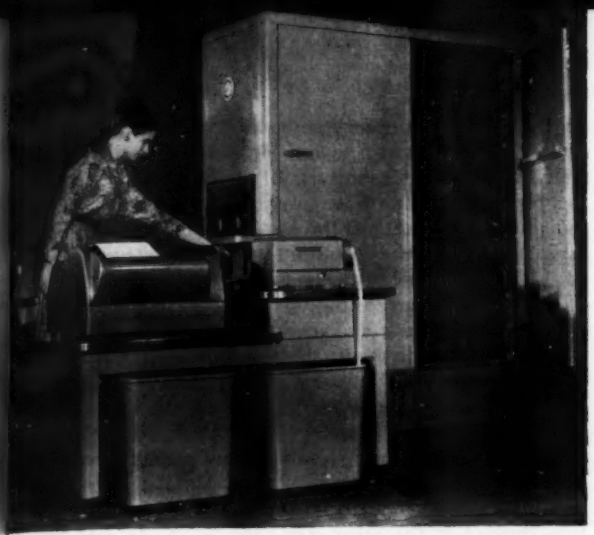
THE PAPER DESCRIBES AN ELECTRONIC RELAY DESIGNED to protect electrical machines under over-current conditions. The advantages of this device over conventional thermal and magnetic protective relays are outlined, and methods of connection for single- and multi-phase working are discussed. 621.316.925 : 621.313

Non-Destructive Testing of Liquids

A synopsis of a Measurement and Control Section paper (No. 2146) entitled 'The Non-Destructive Testing of Electric Strength of Liquids', by W. P. Baker, B.Sc.(Eng.), Associate Member. The paper is published this month in Part A of the Proceedings.

THE DEVELOPMENT OF AN 80 KV BREAKDOWN TESTING equipment, designed for the non-destructive breakdown testing of liquids, is described. The equipment is so designed that, within one or two microseconds from the initiation of a breakdown, the source of high voltage is short-circuited by means of a special form of three-sphere gap, and consequently the energy dissipated in the breakdown path is little more than that stored in the self-capacitance of the electrode assembly.

The equipment is particularly suited to the testing of transformer oil, and about 5000 breakdown tests have been carried out on one sample of oil without any evidence of the formation of carbon. Some data are included of test results obtained during research into the mechanism of oil breakdown. 621.317.333.6



The Convention on Digital-Computer Techniques

At the recent Convention on Digital-Computer Techniques held at the Institution building from the 9th to 14th April, 1956, engineers and others interested in computers from all over the world met to discuss the latest developments in this rapidly expanding subject. This report gives a brief account of some aspects of this successful Convention. Short reviews of the papers are appearing in this and future issues of the Journal (see p. 476).

It is only ten years since the first electronic calculating machine—the ENIAC—was produced in America, and since that time a very great amount of research has been done on such machines all over the world. With the infant science growing at such a lusty rate it is useful to hold occasional conferences for the exchange of ideas on its upbringing. Three major conventions have been held in this country—at Cambridge in June, 1949, at Manchester in July, 1951, and at the National Physical Laboratory in March, 1953—and that the time was ripe (or, some may think, overripe) for another is shown by the attendance of 1 423 people at the recent Convention on Digital-Computer Techniques, organized jointly by the Department of Scientific and Industrial Research and The Institution. This number represents a record for The Institution's meetings, and the Convention was the largest on this subject so far held in this country. The interest which it aroused was widespread, and visitors from the Continent, Australia, Finland, India, Japan, Russia, Sweden, and the United States were among the packed audiences in the Lecture Theatre and the overflow meetings.

At the Opening Session on Monday evening, the 9th April, the Lecture Theatre was crowded to capacity, and two overflow meetings were held, the proceedings being followed by closed-circuit television on a dozen screens in the common-room and the E.L.M.A. lecture room on the top floor of the Institution building. In his introductory remarks the President, Sir George Nelson, made the point that the calculating machine is not a new invention. The human hand and counting frame are the most elementary examples, and mechanical computing machines have a venerable history. However, the application of electronics in the last few years has resulted in rapid developments. He stressed that, although research is still going on, digital machines are already in a state where they can make a real contribution to science and industry, and there need be no tendency to await further developments before utilizing these devices. He then invited Sir Cyril Hinshelwood, President of the Royal Society, to give the opening Address to the Convention.

Sir Cyril contemplated the 'extremely diverse tributaries of thought which have flowed together to constitute the modern stream'. Without man's abstract interest in philosophy, logic and the theory of numbers, the subject would never have started, and without a host of apparently unrelated discoveries in electricity and magnetism the digital computer would never have been a practical possibility. Turning to the future, he said that the wide introduction of machines would solve and create many social problems, and would ultimately give rise to profound changes in the organization of society. One problem it may solve is that of the steady downgrading of the clerical worker. He lucidly discussed the analogies between computers and the human brain, behaviourism and the problems of mind and matter. Although he was careful not to be dogmatic, it was clear that he considered (like most scientists and engineers to-day) that a man's brain was essentially different from a digital computer in its free-will and its capacity for feeling.

After Sir Cyril's scholarly Address, Professor F. C. Williams delivered the Introductory Lecture. Professor Williams, of Manchester University, has been in the van of digital-computer development work for many years, and his lecture was given in a fresh, breezy style that ranged effortlessly over the whole vast field. He stressed the advantages of speed, automatism and capability of tackling all problems that yield to numerical analysis.

Dealing with the errors made by machines he said that a rate of one mistake an hour is an unfair way of looking at it, for in that hour the machine can perform 4 000 000 operations, and a quarter of a mistake per million operations represents a high degree of accuracy. Besides, error rates much lower than this can be achieved in modern machines, and, moreover, the machine can be made to check its own answers.

Calculations on machines that are used continuously are cheap compared with those carried out by the human brain, even though the initial cost may be about £100 000,

and the running cost £10000 a year. To exemplify this he introduced a unit called the 'girl-second', and showed that for the cost of performing a 12-figure multiplication on a computer a girl clerk could be hired for a quarter of a second. Where a machine is used for purely routine operations it is fairly simple to keep it fully occupied, but for the more extensive programming required for scientific work, a large number of mathematicians have to be employed. At Manchester about 50 mathematicians are kept continuously employed and their combined annual salaries make the initial cost of the machine look like 'chicken-feed'. However the machine should not be penalized for the salary bill of its operators, since a much larger bill would be necessary without it.

The first electronic machines to be used for computing represented a revolutionary step forward, but the 'second-generation' machines now becoming available, while being cheaper, smaller, faster and easier to programme, do not show an advance in any way comparable. He was of the opinion that we shall not see such an advance for a very long time, and development will now become a matter of improvement and evolution, such as that made possible by the transistor. The initial surge of discovery is largely over, and a period of application lies ahead. Among these applications are many commercial uses—industrial process control, the design of structures, the forecasting of weather, and possibly even the translation of languages.

The opening session gave an admirable start to a week of keen activity. Two series of sessions were held simultaneously, a General series which dealt with the construction, performance and applications of the machines as a whole, and a Specialist series on individual techniques and the design of selected components of the machines, although in practice these two series overlapped a good deal. All the sessions, throughout the morning, afternoon and evening were packed, and overflow meetings were a regular feature throughout the week. It appeared that some members actually preferred the overflow meetings, where in the comfort of a deep armchair in the common-room they could not only watch the proceedings clearly reproduced on the television screen but could smoke as well. In all the sessions—both General and Specialist—emphasis was placed on the discussions, which were usually stimulating, and became heated when such questions as reliability and the relative merits of analogue and digital computers arose—which they often did.

For example, in the second General session dealing with the engineering and scientific applications of digital computers, the 'analogue-versus-digital skirmish' (as Mr. A. W. Hales called it) occupied much of the discussion. The application of digital computers to many of the problems was criticized by several speakers. Dr. J. R. Mortlock said that the load-flow problem—the subject of a paper by Dr. J. M. Bennett—was amenable to solution on the a.c. network analyser and gave interesting figures for the times of operation—145 minutes on the analyser compared with 489 minutes on the digital computer—and said that the cost of the former was very much lower. He also claimed, for the analyser, greater flexibility and closer connection with the physical reality of the problem. However, he conceded the accuracy of the digital computer, and its applicability to the determination of system losses. Mr. M. W. Humphrey Davies, replying in the absence of Dr. Bennett, agreed that there was much in favour of analogue computers, and advised system engineers 'not to worry about anybody shutting down their network analysers, but to look at some of the problems which they are not able to tackle at the present time and see whether or not a digital computer could do it for them'. Mr. B. Higman also deprecated strongly any advocacy of one type of machine against the other since neither could do its full job without a certain backing up by the information derived in the other way. Mr. R. K. Livesey was interested in a paper by Miss B. M. Dent and Mr. B. Birtwistle because it represented 'the application of a digital computer by what one may call a customer, someone who . . . has no axe to grind'. From their conclusions it is apparent that there are many cases where the unbiased person prefers the digital computer. For Mr. A. Ridlington, the general conclusion to be derived from the discussion was that for accuracy the digital machine has the advantage, for speed they are roughly similar but for flexibility the analogue machine is much to be preferred.

The interesting and controversial question of the application of digital computers in industrial control was discussed in the fourth General session. Dr. I. J. Faulkner, the opening speaker, pointed out that industrial control seldom calls for extremely rapid and accurate calculations. Rather does it demand features which, so far as digital computers are concerned, are almost incidentals—features such as the storage and manipulation of large numbers of observations. He said that the field was almost untouched, not through lack of enthusiasm on the part of engineers but because a job of any magnitude would cost at least £25000. He reviewed two applications which have so far been found economically worth while—machine-tool controlling and freight-yard shunting—and suggested that there may be other applications in the chemical industry. He closed by asserting that in ten years' time digital computers will have taken a prominent place in industrial control.

In the ensuing discussion reliability was the keynote. While it was recognized by Dr. M. V. Wilkes that electronic devices are equally as reliable as mechanical ones of comparable complexity, the digital computers are so complex that they are apt to be less reliable on the whole. He thought it might be better to connect the machine to the manager instead of to the plant! Mr. H. S. Bray also criticized digital computers on the score of reliability. One mistake per hour, he said, was not good enough, but Mr. R. H. Tizard pointed out that computers could be used to advise the normal automatic controllers, which would maintain order if the computer went wrong. Mr. E. A. Newman, taking a longer view of the

subject, suggested that reliability may be obtained only by a redesign of logical devices along the lines of the human brain.

Transistors rightly received much attention in two sessions of the Convention, for, as Dr. R. C. G. Williams mentioned, their rather peculiar attributes in non-linear applications make them particularly suitable for use in computers. Mr. T. R. Scott gave a comprehensive lecture on *The Present State of Development and Future Prospects of Transistors*, and Mr. E. H. Cooke-Yarborough, the opening speaker, gave an account of *The Transistor as a Computing Element*. The field covered by these lectures and the subsequent papers was very wide, and readers who are interested are referred to the actual texts. In the discussion Mr. E. Wolfendale made the important point that commercial machines must be based on devices which will be in mass production when the computer design is ready. This is necessary to ensure that a supply of the devices is available—and available at an economic price. On the ever recurring theme of reliability, Mr. Wolfendale said that in his experience the junction transistor is considerably more reliable than the thermionic valve. Mr. I. S. Walker, on the other hand, said that his own experience (admittedly less) indicated a transistor failure rate as high as 24% per 1 000 hours, compared with 1% for thermionic valves.

The last General session on Thursday evening allowed a free rein to the imagination. In the words of Dr. A. D. Booth it was 'rather like a discussion after a dinner—not to be taken too seriously but nevertheless leaving one with pleasant memories of the meeting'. Under the august heading 'Discussion on the Computer in a Non-Arithmetic Role', lecturers from Britain, America and Russia regaled members with fascinating accounts of the playing of draughts and other games, the automatic reading of printed characters, and the electronic translation of languages. A paper on this last subject, by Dr. I. S. Mukhin, gave a vivid account of Russian work, though members reserved not a little of their interest for the demure interpreter who accompanied him.

From theory and discussion the Convention moved to hard reality. Friday and Saturday were devoted to excursions to well-known digital-computer installations, including some as far away as Harwell, Cambridge and Manchester, where members could appreciate the impressive size, speed and performance of the actual machines. The visits provided light relief and a fitting conclusion to a stimulating and hard-working week.

As announced in the July *Journal*, p. 446, the proceedings of the Convention will be published as three special Supplements to the *Proceedings* of The Institution in the autumn of this year. Order forms for these Supplements may be obtained from the Secretary.

MONOGRAPHS AND PAPERS

published individually this month

Synopses of monographs and papers published individually before the next issue of the Journal are given below, and, unless otherwise stated, their dates of publication are this month. Reprints of all papers are available about two months after publication in the Proceedings. The prices shown below are post free. When ordering please quote serial number of paper or monograph. Books of 8 vouchers may be obtained from the Secretary, price 10s. each.

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MONOGRAPHS

A Method for the Approximate Determination of the Impulse Response of a Number of Identical Circuits in Cascade

MONOGRAPH No. 189 R

K. F. SANDER, M.A., Ph.D.

The method of steepest descents is applied to evaluate the impulse response of a number of identical circuits in cascade. It is shown that exact results may be obtained by analogue computing. Approximate analytical expressions are obtained for various values of time, including the period of build-up. These are tested against two networks for which exact evaluation is possible. A cruder approximation valid for values of time near the build-up value is applied to predict suitable parameters for video compensating networks. These again are checked with known results.

The Use of Lossy Material to Suppress Unwanted Modes in Cavity Resonators

MONOGRAPH No. 190 R

M. Y. EL-IBIARY, B.Sc., Ph.D., and J. BROWN, M.A., Ph.D.

Unwanted modes in cylindrical cavity resonators operating in the H_{01n} mode may be suppressed by inserting a ring of lossy material in a groove cut at the junction between an end wall and the cylindrical wall. This groove does not affect the

H_{01n} mode but may suppress the others if the groove dimensions are correctly chosen. An analysis of the effectiveness of this method is given and is confirmed by measurements in the 3 cm band of wavelengths.

Hall Effect and its Counterpart, Radiation Pressure, in Microwave Power Measurement

MONOGRAPH No. 191 R

PROFESSOR H. E. M. BARLOW, Ph.D., B.Sc.(Eng.)

Hall effect and radiation pressure are shown to be different manifestations of the same basic phenomenon, and their relationship is deduced for a plane wave transmitted through a slab of material of given electrical characteristics. In particular, the contributions to these effects of both the conduction and displacement components of current in the material are examined, and it is shown that the latter can be a significant supplementary factor at ultra-high frequencies.

Both Hall effect and radiation pressure have been used for microwave power measurement, and some aspects of these applications are discussed in the light of the present analysis. To permit a better assessment of the Hall-effect wattmeter problem, numerical calculations have been made at 4 000 Mc/s for *n*-type germanium and silicon, showing that a high-resistivity material is necessary to achieve a satisfactory performance with a transmission type of instrument. Similar computations for polythene predict that a measurable Hall effect arising from displacement current in this material should exist, and it is suggested that observations based on that effect might offer a new approach in further exploration of the properties of dielectrics.

Propagation over a Discontinuity in the Earth's Electrical Properties: I

MONOGRAPH No. 192 R

T. B. A. SENIOR, M.Sc., Ph.D.

The problem considered is one in which vertically-polarized radio waves are propagated across the line of a single straight-line discontinuity in the electrical properties of a smooth flat earth, the discontinuity being such as might occur at a (rather idealized) coastline. It is assumed that one of the media (e.g. sea) has infinite conductivity and this is replaced by an infinitely thin, perfectly conducting half-plane lying in the interface of the air and the land medium.

With this model a method of solution is proposed which is a union of ray theory and rigorous diffraction theory. The land is allowed for by the introduction of a suitable image field and the problem becomes one of two fields incident upon a perfectly conducting sheet in free space. The technique is illustrated by application to a three-dimensional plane wave, and the solution forms the basis of later work.

When the transmitter is at a finite distance from the coastline the solution can be obtained by expressing the incident field as an angular spectrum of plane waves whose propagation has already been studied. This procedure is first applied to the two-dimensional problem of a line source and the results are shown to agree closely with previous work on the subject.

The author studies the nature of the field with particular reference to the rapid changes of intensity and phase just beyond the coastline; the former is generally termed the *recovery effect*, whilst the latter gives rise to the phenomenon of coastal refraction. The use of height-gain factors is also considered, and several numerical examples are given.

Characteristics of the Trigatron Spark-Gap

MONOGRAPH No. 193 M

A. M. SLETTEN, and T. J. LEWIS, M.Sc., Ph.D.

The behaviour of a Trigatron three-electrode spark-gap in air has been investigated and its characteristics obtained with particular reference to its use as a controlled high-voltage switch. It is found that the voltage range over which it may be triggered satisfactorily depends, not only on the polarities of the main gap and triggering voltages, but also on the energy of the discharge. The breakdown time-lag is also determined by these same voltage polarities and also by the time-constant of the trigger-discharge circuit. From these characteristics and certain other relevant observations, a theory of the breakdown process in such a spark gap is suggested, involving the propagation from the trigger of a low-density, easily-ionized region.

Synthesis of Transmission Systems in Terms of Tandem-Connected Quadripoles

MONOGRAPH No. 194

P. W. SEYMOUR, and S. DØSSING, M.Sc.(Eng.)

A theory for the tandem connection of quadripoles is presented, using as basic parameters the operating factor and input and output impedances of a quadripole which operates under reference conditions between arbitrarily chosen source and load impedances.

Operating-loss and input-return-loss formulae are derived for the non-reference operation of a quadripole, and, in conjunction with return-loss formulae obtained for quadripole junctions, are used to determine overall operating-loss characteristics of a transmission system when quadripoles are added or removed. A technique is developed which permits convenient and precise calculation of return and operating loss.

The formulae derived facilitate the rapid solution of a variety of practical transmission problems, and their application in some instances is illustrated by the inclusion of numerical examples.

PAPERS

Insulation Properties of Compressed Electronegative Gases

PAPER No. 2128 M; PART B

P. R. HOWARD, Ph.D., B.Sc.(Eng.)

The electrical insulating properties under pressure of a number of halogenated methane compounds and sulphur hexafluoride are compared; sphere-sphere and point-sphere electrode configurations, and alternating, direct and impulse voltages are used. The influence of irradiation is also investigated. Of the gases studied, sulphur hexafluoride and difluorodichloromethane (known commercially as Arcton 6) have the most favourable properties for high-voltage insulation, and additional data are provided for the comparison of these two gaseous compounds.

The author compares data for electro-negative gases with corresponding data for nitrogen under the same conditions and with transformer oil at atmospheric pressure.

Chemical and physical properties, such as vapour-pressure characteristics, and economic factors are considered in assessing the suitability of sulphur hexafluoride and difluorodichloromethane as insulants for high-voltage equipments.

An Experimental Study of High-Permeability Nickel-Iron Alloys

PAPER No. 2136 M; PART B

C. E. RICHARDS, F.R.I.C., E. V. WALKER, B.Sc., and A. C. LYNCH, M.A., B.Sc.

Commercial alloys are often disappointing in having lower permeabilities and higher losses than would be expected from published data; this is particularly so for very thin strips or sheets. These inconsistent supplies embarrass designers of electrical equipment. The authors have studied factors which might influence either the ultimate performance or the consistency of the metals, with particular reference to the 77/14/5/4 nickel-iron-copper-molybdenum alloy, using samples made by powder metallurgy.

If high permeabilities are to be attained the permissible tolerance on composition is very small, the value for iron and nickel being only $\pm 0{\cdot}2\%$; furthermore any introduction of silicon makes the alloy susceptible to damage by water vapour in the annealing atmosphere. With conventional melting techniques it is difficult to hold such tolerances and to avoid contamination by silicon. The types of low-permeability layer which have been previously reported are not intrinsic and are probably due to impure metal which has been unsatisfactorily or incompletely annealed.

An Improved Fading Machine

PAPER No. 2150 R; PART B

H. B. LAW, B.Sc.Tech., F. J. LEE, R. C. LOOSER, B.Sc.(Eng.), and F. A. W. LEVETT

A fading machine which formerly gave cyclic fading has been modified to give substantially random fading with the amplitude of the signal conforming to the Rayleigh distribution, as with long-distance h.f. radio signals. The fading is obtained by combining six components in random phase. The machine simulates propagation by up to three paths with a spread of up to 2 millisec in path-time delay and caters for dual diversity reception. It has proved to be a valuable tool in laboratory investigations of radiotelegraph equipment.

Frequency Diversity in the Reception of Selectively Fading Binary Frequency-Modulated Signals, with special reference to Long-Distance Radiotelegraphy

PAPER No. 2151 R; PART B

J. W. ALLNATT, B.Sc.(Eng.), E. D. J. JONES and H. B. LAW, B.Sc.Tech.

In current long-distance h.f. radio practice, frequency-shift-telegraphy signals are usually demodulated by the use of limiters and discriminators on conventional frequency-modulation lines. The demodulation is liable to fail whenever the signal fades on either the mark frequency or the space frequency. This is wasteful. The full message is available on each frequency, and failure need not occur unless signals on both fade together; if the fading is frequency-selective, as it often is, simultaneous fading may be comparatively rare. Thus there is the possibility of frequency diversity.

Theoretical analysis of the case of Rayleigh-fading signals disturbed by white Gaussian noise, the fading being slow relative to the speed of signalling, shows that substantial advantages may be derived from frequency diversity. Also, the analysis leads to a mathematical specification for an ideal receiver. An experimental equipment has been made, which, while avoiding the complexity that full accord with the specification would involve, complies with it in several respects.

Laboratory tests on the experimental unit gave results in good agreement with theory. At the optimum signalling speed the noisy-signal performance was only about 3 dB short of the ideal.

An Investigation of the Spectra of Binary Frequency-Modulated Signals with Various Build-Up Waveforms

PAPER No. 2152 R; PART B

J. W. ALLNATT, B.Sc.(Eng.) and E. D. J. JONES

It is found that a straight-line waveform is the best that can be employed for the transition between mark and space frequencies in frequency-shift radiotelegraphy, since this waveform involves the minimum occupied bandwidth for a given total build-up time. Data on the spectra of frequency-shift signals using straight-line build-up, i.e. a trapezoidal waveform, are presented for modulation indices between 1 and 6 and build-up times between 0 and 0·31 of a telegraph element. Although the work was initiated for radiotelegraphy, the results are, of course, applicable to frequency-modulated signals generally.

Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33 kV and Above

PAPER No. 2158 S; PART A

A. MORRIS THOMAS, B.Sc., and D. F. OAKESHOTT, B.Sc.

The paper is essentially a short critical résumé of the factors which determine the security of h.v. a.c. overhead-line transmission systems, with a description of methods that provide a logical basis for the choice of insulation levels.

Transient over-voltages are the main danger to overhead-line insulation. These may be of internal origin, but lightning strokes are the chief source, particularly in countries oversea where lightning is prevalent. Lightning phenomena are therefore considered in the paper. The problem of shielding by earth wires and the importance of tower-footing resistance are discussed. A description of the characteristics of line insulation is given; this includes data on power frequency and impulse tests, flashover voltages, atmospheric influences, deterioration, use of wood poles, and other related matters.

The selection of insulation levels involves a careful consideration of the above factors with, in addition, a means of estimating line reliability. Two methods are described which have been developed for predicting line performance under lightning conditions.

LEAD NEWS

The first issue of a new periodical entitled *Lead News* has recently been published. The aim of *Lead News* is to supply authoritative information to users on the many ways lead can be employed in modern production. The first issue includes some short technical articles and notes of interest to electrical engineers, such as 'The Use of Lead in Atomic Energy', 'New Batteries for Specialized Applications' and 'Advances in Electro-Deposition'. *Lead News* is well laid out and produced; busy engineers who are interested in reading it may be glad to know that the first issue contains only eight quarto pages. The publishers, who are The Lead Development Association, Eagle House, Jermyn Street, S.W.1, do not state how frequently the periodical will appear.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 2nd July, 1956.

ELECTIONS

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BURGHARD, Rear-Admiral Geoffrey Frederic, C.B., D.S.O., R.N.(RET.).

Associate Members

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COSHAN, Douglas Conrad Martin, B.SC.
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GRANT, Braham.
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JAIN, Ajit Pershad.
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KINGRAVI, Lt.-Col. Iftikhar Ahmad, R.P.E.
KITCHING, John Kenneth.
LIGHT, Leon Henry, B.SC.
MOORE, Denis van der Meulen.
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PARGETER, Harry Osborne.
RAGAB, Mohamed Mohamed, B.SC.
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SQUIRE, John Francis.
STONE, Charles Francis.
TRICKEY, Philip Harold, M.S., E.E.

Associates

APPLEBY, Mark.
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FOSTER, Albert Edward.
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SHAWEESH, Hamzeh Mohamed.
WELSH, James Henry.

TRANSFERS

Associate Member to Member

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EVANS, Emlyn Rees, B.SC.
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JOWETT, John Kenneth Savile, B.SC. (ENG.).
KNOTT, George, M.A.
McGEE, James Dwyer, O.B.E., M.SC., PH.D.
PAGE, Harold, M.SC.
PATCHETT, Gerald Norman, B.SC., PH.D.
SANDISON, John Peter, B.SC.
WAIN, Leslie.

Associate to Associate Member

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Graduate to Associate Member

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BARTER, Anthony Arthur, B.SC.
BELL, Donald.
BENJAMIN, Samuel, B.SC.(ENG.).
BEST, Raymond William George.
BLABEY, Gordon.
BLACK, Keith Marriott.
BROWN, Dennis George.
BYRNES, James William.
CANN, Eric Reginald Morgan, B.ENG.
COLLEN, Ralph Donald.
COOPER, Basil Charles James.
CRANK, Geoffrey James, B.SC.(ENG.).
DUTTON, Stanley.
DYKES, Thomas Cunninghame.
ELLIOTT, Capt. George Francis, B.SC., R.E.M.E.
EVERETT, Edward.
FARR, Charles Albert.
FRANKLIN, Raymond Victor.
FROST, Edward James.
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GREEN, Eric.
GREEN, John.
HARRISON, Hubert Lodge.
HIBBERT, John, B.SC.TECH.
HOLT, Norman John.
HOWE, Jack Clifford, M.SC.(ENG.).
KELLY, Michael.
KENWORTHY, Derek Read, B.SC. (ENG.).
LANGFORD, Brian, B.SC.(ENG.).
LEVINGE, Rodney Walter.
LLOYD, Wilfred Edwin, B.SC.TECH.
MACDONALD, Ian Morrison, B.SC.
MAIN, John William.
MALAIKA, Ahmed Isa, B.SC.
MALBON, Harry, B.SC.
MIDGLEY, Frank Booth, B.SC.(ENG.).
MURRAY, Thomas Bryce, B.SC.
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OWEN, Alfred Richard.
PARKES, Malcolm Campbell, B.SC.
PUCILL, Peter Melburn, B.A.
ROBINSON, Ernest Leslie.
ROBINSON, Rodney Vernon.
ROTHERMEL, Frederick Thomas, B.SC.(ENG.).
SEN, Paresh Chandra, B.SC.TECH.
SHARPE, Gerald, B.SC.(ENG.).
SHIER, Eric Adam, B.SC.(ENG.).
SIMPSON, Peter John.
SIMS, Donald Henry.

Graduate to Associate Member—(contd.)

SNAILUM, Peter Reginald William, B.ENG.
SNELLING, Eric Charles, B.SC.(ENG.).
SUTHERLAND, Ian Robert.
TAIYEB, Ali, B.SC., B.SC.TECH.
TASKER, Frank James David.
TAYLOR, Joseph Cook.
TEKANT, Ahmet Naim, M.SC.
TINKER, Peter Frank.
TREND, David John Farina.
WALKER, Norman.
WALKER, William Andrew.
WEBSTER, John William.
WHARTON, John Clive, B.SC.
WILLIAMS, John Francis Rowberry.
WONG, Yin Khoon, B.SC.
WOOLDRIDGE, Peter Alexander Borger.
WYATT, Frederick Roy.
WYMAN, Kenneth Henry.

Student to Associate Member

BEAUMONT, Eric.
PRIOR, Peter Malcolm, B.SC.(ENG.).
WISE, Lt.-Cmdr. Lancelot Evelyn Dacres, R.N.

Student to Associate

HOMER, Thomas.

The following elections and transfers approved by the Council are effective from the 21st June, 1956.

ELECTIONS

Graduates

ALLCOCK, Peter David.
ALLMARK, Peter Roy.
ANDERSON, Alan Patrick, B.SC.
APPERLEY, Eric Charles, B.SC.
ARNOLD, Derek.
AYRTON, Sammy Shavux, B.SC.
BACKER, Arnt, B.SC.
BAUMGARTNER, Hans, DIPL.ING.
BONTA, Arthur John.
CIALLELLA, Vincenzo, DR.ING.
COFFEY, Patrick Joseph.
DEAKIN, Trevor Hugh Guy.
EDWARDS, Raymond.
ELLWOOD, Thomas Henry.
FREEMAN, Ronald, B.SC.(ENG.).
GAWNE, Robert John, B.E.E.
GLIDE, Ronald William Frederick.
GOOD, Joseph Rodney.
GRANT, Brian Eric, B.SC.
HOLDER, Charles James.
JEREMY, Kenneth William Charles.
JONES, David Alfred.
JONES, Eric.
KING, Desmond.
KLEYN, Frederik Evan, B.SC.(ENG.).
KRUITHOF, Albert.
LISTER, James William.
MANCA, Giuseppe, DR.ING.
MORRIS, Sydney James.
MULVANEY, Capt. John Edward, R.E.M.E.
NICHOLSON, John.
OLD, John Derek.
QUARTERMAIN, Cyril Arthur.
REEVES, Raymond Leslie.
RICHARDS, John Holland, B.SC. (ENG.).
RICHARDSON, Leslie.
SMITH, Michael Ernest.
SZMIDT, Witold.
TALBOT, William John.
TONKS, John Harold, B.SC.
WAN MOHD DAUD, Bin Wan Ibrahim, B.SC.(ENG.).
WHEELER, William John.

Students

ADAMS, Peter Samuel.
ASHE, David Arnold, B.SC.
BAILEY, Allan Frank.
BARR, John Lawrence.
BATTYE, David.
BEACHELL, Iain Alexander.
BENGO, Henry.
BLOXHAM, David Arthur.
BRIDGE, Rodney James.
BROWN, Derek Graham.
BUCKLEY, Charles Raymond.
CANNON, John William.
CHANIAS, Constantine John.
DAVEY, George Stuart.
DAVIES, David.
DE COITO, John Augusto.
DEVONALD, Vernon Lewis.
DICKSON, Richard James.
DIXON, James Maurice.
DOBBIN, William Charles Henry.
ELLIS, Geoffrey David.
FORD, George.
GOLDING, Robert John.
HARDS, David John.
HEARD, Roger Nigel.
HENWOOD, David John.
HODGSON, John Ernest.
HOLLAND, Brian Alfred, B.SC.(ENG.).
HOWE, Derek.
HUGHES, Robert Gordon.
HUNT, Antony John.
HURLSTON, Frank David.
HUTCHINGS, Norman Frank.
ISRAEL, Albert.
JAMES, Roy Arthur.
JINDAL, Sat Parkash, B.A.
KHULLER, Amrit Rai, B.A.
LANGLEY, Ivan John.
LIFFEN, Daniel.
MACKENZIE, Alexander Miller.
MAHER, John Joseph.
MARLTON, Paul.
MARTIN, John David.
MARTLEW, Allan.
MING, Lu.
MOGG, Ronald Murray.
NEWCOMBE, John.
PARK, James William.
PHILLIPS, Gwilym John.
PHILLPOTTS, Raymond Martin.
PLUMMER, Barry Ernest William.
REED, Donald David.
ROSE, David William.
SAMBASIVAM, Thiagarajah.
SHAHEEN, Hazim.
SKINNER, James Reginald.
SWIFT, Graham George.
THOMAS, Peter John.
TYSON, Edwin, B.A.
TYSON, John Edward.
VERTH, Colin Carse.
WING, Graham Robert.

TRANSFERS

Student to Graduate

BOWDEN, Colin Morgan, B.SC.
BROWN, Donald Geoffrey.
COVENTRY, Randall James.
CROWE, John Phelps.
DUBEY, Chandra Varty, B.SC.
ELLEM, Neville James.
EMBLETON, Desmond Victor.
FLANDERS, Richard David.
GETGOOD, Ronald Arthur Stanley, B.SC.(ENG.).
HARROP, James Jones.
HIGGINSON, Peter Roy.
HUSAIN, Manzoor, B.SC.
ILUMOKA, Emanuel Oladipo.

Student to Graduate—(contd.)

JACKSON, Berkeley Cunliffe.
JONES, Kenneth Robert, B.ENG.
JURKIEWICZ, Edmund.
LEE, Sian Phin.
McGILL, Jeffrey Charles.
MARCHANT, John James, B.SC. (ENG.).
O'CONNELL, Kevin John, B.E., B.SC.
PATTERSON, George William Rowland, B.SC.
PAYNE, Gladstone Olumide.
PEARSON, James Richard, B.SC.
ROGERS, Alan John.
SHEARMAN, John Barry.
SMITH, Eric Alwyne, B.SC.
TAVERNER, Arthur Ian, B.SC.
WALKER, Lyle, B.SC.(ENG.).
WOODS, John Joseph.
WOOLLEY, George Edward, B.SC.

LIBRARY ACCESSIONS

PUBLICATIONS OTHER THAN BOOKS

'ELECTRICAL MANUFACTURING'

Electrical Insulation and Dielectrics 1955. An 'Electrical Manufacturing' Design Annual

New York, Gage Publishing Company, 1955. pp. 130. 28 × 22 cm. 24s. approx.

HARRIS, J. D., and MORICE, P. B.

Prestressed Concrete

London, Cement and Concrete Association, 1952. pp. 64. 25 × 18 cm.

INTERNATIONAL SCIENTIFIC RADIO UNION

Proceedings of the XIth General Assembly held in The Hague from August 23rd to September 2nd, 1954. Volume X. Part 7. Commission VII on Radioelectronics

Brussels, U.R.S.I., 1954. pp. 140. 24 × 16 cm.

MINISTRY OF EDUCATION and SECRETARY OF STATE FOR SCOTLAND

Technical Education

London, H.M.S.O., 1956. pp. 43. 24 × 15 cm. 1s. 6d.

MINISTRY OF FUEL AND POWER

British Trials in Underground Gasification 1949–1955

London, H.M.S.O., 1956. pp. iv, 90. 33 × 20 cm. 8s.

MINISTRY OF FUEL AND POWER

Report of the Committee of Inquiry into the Electricity Supply Industry. Chairman: Sir Edwin Herbert

London, H.M.S.O., 1956. pp. viii, 189. 24 × 15 cm. 6s. 6d.

MINISTRY OF LABOUR AND NATIONAL SERVICE

Electrical Accidents and Their Causes 1953

London, H.M.S.O., 1955. pp. 60. 24 × 15 cm. 3s.

MINISTRY OF SUPPLY

Bibliography of Information on Servomechanisms and Related Subjects. Addendum No. 2

London, Ministry of Supply, 1955. pp. 143. 33 × 20 cm.

MINISTRY OF WORKS

Basic Design Temperatures for Space-Heating. By a Study Committee convened by the Councils of The Institution of Mechanical Engineers, The Institution of Electrical Engineers, The Institution of Gas Engineers and The Institution of Heating and Ventilating Engineers (Post-War Building Studies No. 33)

London, H.M.S.O., 1955. pp. vi, 89. 24 × 15 cm. 3s. 6d.

NATIONAL BUREAU OF STANDARDS, UNITED STATES DEPARTMENT OF COMMERCE

Copper Wire Tables (Circular No. 31)

4th ed. Washington, U.S. Government Printing Office, 1956. pp. iv, 36. 26 × 20 cm.

NATIONAL BUREAU OF STANDARDS, UNITED STATES DEPARTMENT OF COMMERCE

Guide to Instrumentation Literature (Circular No. 567)

Washington, U.S. Government Printing Office, 1955. pp. 156. 26 × 20 cm.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD

Annual Report and Statement of Accounts 1st January, 1955, to 31st December, 1955. And the Report of the Electricity Consultative Council for the North of Scotland District.

Edinburgh, H.M.S.O., 1956. pp. 71. 24 × 15 cm. 3s. 6d.

OFFICE MANAGEMENT ASSOCIATION

The Scope for Electronic Computers in the Office

London, Office Management Association, 1955. pp. 102. 24 × 18 cm. 15s.

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

The Electricity Supply Industry in Europe. Trends in economic sectors

Paris, O.E.E.C., 1956. pp. 132. 24 × 15 cm.

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

The Organisation for European Economic Co-operation. History and structure

5th ed. Paris, O.E.E.C., 1956. pp. 45. 24 × 15 cm.

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

Seventh Report of the O.E.E.C. Economic expansion and its problems

Paris, O.E.E.C., 1956. pp. 298. 24 × 15 cm.

PHYSICAL SOCIETY

Year Book of the Physical Society. Containing special Lectures delivered before the Society; Obituaries; Proceedings of Meetings of the Society; Report of the Council for 1954 and Accounts and Balance Sheet for 1954.

London, The Physical Society, 1955. pp. 92. 26 × 18 cm. 10s. 6d.

SHORTER, D. E. L., and HARWOOD, H. D.

The Design of a Ribbon Type Pressure-Gradient Microphone for Broadcast Transmission

London, British Broadcasting Corporation, 1955. pp. 22. 28 × 21 cm. 5s.

UNITED NATIONS

Proceedings of the International Conference on the Peaceful Uses of Atomic Energy. Held in Geneva, 8th August to 20th August, 1955. Volumes 1–16.

New York, United Nations, 1956. 28 × 22 cm. £39.

WIGGIN, HENRY, AND COMPANY

Development of Alloys for Electric Heating Elements

Birmingham, Henry Wiggin and Co., 1955. pp. 20. 23 × 15 cm.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 23RD JULY, 1956

	No. of Contributors	£	s.	d.
£1 000 and over	6	6 000	0	0
£100 to <£1 000	29	6 386	3	0
£5 to <£100	785	8 553	6	5
£2 to <£5	1 908	5 263	2	2
Under £2	19 659	10 303	10	3
		£36 506	1	10

CONVENTION ON ELECTRICAL EQUIPMENT OF AIRCRAFT

An order form for copies of the special Supplement relating to the Convention on Electrical Equipment of Aircraft is being enclosed this month to all subscribers to Part A of the *Proceedings*. Any members or others who do not subscribe to this Part may obtain a copy of the order form on application to the Secretary. It is expected that the Supplement will be issued in December next, the price to members being 15s., and to non-members £1 10s.

Those who have already ordered copies on the registration form issued in advance of the Convention are not required to take any further action.

PREMIUMS

The Council have made the following awards of premiums for papers during the 1955–56 Session:

GROUP A

The Institution Premium (value £50)

T. H. Kinman, M.B.E., G. A. Carrick, M.A., R. G. Hibberd, B.SC., and A. J. Blundell — 'Germanium and Silicon Power Rectifiers'

The Kelvin Premium (value £25)

A. Stott, M.A., and P. E. Axon, O.B.E., PH.D., M.SC. — 'The Subjective Discrimination of Pitch and Amplitude Fluctuations in Recording Systems'

The John Hopkinson Premium (value £25)

S. S. Carlisle, M.SC., and G. W. Alderton, B.SC. — 'The Instrumentation of a 14-inch Experimental Rolling Mill'

GROUP B

Non-Section Premiums

The Ayrton Premium (value £20)

D. Major, B.SC., B.A., F. R. Perry, M.SC.TECH., and K. Phillips, M.SC. — 'A 20 MeV Betatron for X-Ray Therapy'

The Llewellyn B. Atkinson Premium (value £10)

Professor E. G. Cullwick, O.B.E., M.A., D.SC. — 'Electromagnetic Momentum and Electron Inertia in a Current Circuit'

Measurement and Control Section Premiums

The Silvanus Thompson Premium (value £20)

Lt.-Cmdr. F. R. J. Spearman, R.N.(RET.), J. J. Gait, M.A., B.SC., A. V. Hemingway, B.SC.(ENG.), and R. W. Hynes, B.SC. — 'Tridac, A Large Analogue Computing Machine'

The Mather Premium (value £10)

T. Kilburn, M.A., PH.D., D.SC., D. B. G. Edwards, PH.D., M.SC., and G. E. Thomas, PH.D., M.SC. — 'The Manchester University Mark II Digital-Computing Machine'

Premiums (value £5)

A. H. M. Arnold, PH.D., D.ENG., and J. J. Hill, B.SC. — 'An Audio-Frequency Dynamometer Wattmeter'

A. B. Gillespie, B.SC. — 'The Control and Instrumentation of a Nuclear Reactor'

D. R. Chick, M.SC., B.SC., and D. P. R. Petrie, M.SC. — 'An Electrostatic Particle Accelerator'

Radio and Telecommunication Section Premiums

The Duddell Premium (value £20)

L. R. F. Harris, M.A. — 'Time Sharing as a Basis for Electronic Telephone Switching: A Switched Highways System'

The Ambrose Fleming Premium (value £10)

Professor A. L. Cullen, PH.D., B.SC., and J. C. Parr, B.SC.(ENG.) — 'A New Perturbation Method for Measuring Microwave Fields in Free Space'

Premiums (value £10)

E. D. R. Shearman, B.SC.(ENG.) — 'A Study of Ionospheric Propagation by Means of Ground Back-Scatter'; 'The Technique of Ionospheric Investigation using Ground Back-Scatter'

G. B. B. Chaplin, M.SC., PH.D. — 'A Point-Contact Transistor Scaling Circuit with 0·4 Microsec Resolution'

G. B. B. Chaplin, M.SC., PH.D., R. E. Hayes, B.SC., and A. R. Owens, M.SC. — 'A Transistor Digital Fast Multiplier with Magnetostrictive Storage'

G. B. B. Chaplin, M.SC., PH.D., and A. R. Owens, M.SC. — 'A Junction-Transistor Scaling Circuit with 2 Microsec Resolution'

Premiums (value £5)

R. G. Robertshaw and W. E. Willshaw, M.B.E., M.SC.TECH. — 'Some Properties of Magnetrons using Spatial-Harmonic Operation'

G. H. Metson, M.C., PH.D., M.SC., B.SC.(ENG.), E. F. Rickard, B.SC., and F. M. Hewlett, B.SC. — 'Some Experiments on the Breakdown of Heater-Cathode Insulation in Oxide-Cathode Receiving Valves'

W. J. Bray, M.SC.(ENG.), J. A. Saxton, D.SC., PH.D., R. W. White, B.SC., and G. W. Luscombe, B.SC. (ENG.) — 'V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication'

Supply Section Premiums

The Sebastian de Ferranti Premium (value £20)

J. S. Møllerhøj, M.SC., A. M. Morgan, B.SC.(ENG.), and C. T. W. Sutton, M.SC.(ENG.) — 'Flat Pressure Cable'

The John Snell Premium (value £10)

H. C. Hall, M.SC., and E. Kelk, M.SC.	'Physical Properties and Impulse Strength of Paper'	

Premiums (value £5)

W. G. Standring, M.A., and R. C. Hughes, B.SC.	'Breakdown under Impulse Voltages of Solid and Liquid Dielectrics in Combination'	
D. H. Lucas, B.A., and M. E. Peplow, B.SC.	'The Measurement of Steam Temperatures in Power Stations'	

Utilization Section Premiums

The Crompton Premium (value £20)

E. L. E. Wheatcroft, M.A., and H. H. C. Barton, B.A.	'The Potentialities of Railway Electrification at the Standard Frequency'	

The Swan Premium (value £10)

J. J. Bates, PH.D., and Professor A. Tustin, M.SC.	'Temperature Rises in Electrical Machines as related to the Properties of Thermal Networks'	
Professor A. Tustin, M.SC., and J. J. Bates, PH.D.	'Temperature Rises in Electrical Machines on Variable Load and with Variable Speed'	
Professor A. Tustin, M.SC., D. F. Nettell, B.SC., and R. Solt, B.SC. (ENG.)	'Performance and Heating Curves for Motors on Short-Run Duties'	

A Premium (value £10)

Professor G. H. Rawcliffe, M.A., D.SC., and B. V. Jayawant, B.ENG.	'The Development of a New 3 : 1 Pole-Changing Motor'	
Professor G. H. Rawcliffe, M.A., D.SC., and B. C. McDermott, B.SC.TECH.	'The Theory of Third-Harmonic and Zero-Sequence Fields'	

Premiums (value £5)

T. H. Barton, B.ENG., PH.D., O. I. Butler, M.SC., and H. Sterling, B.SC.	'The Theory and Characteristics of the 3 : 1 Pole-Changing Induction Motor'	
T. H. Barton, B.ENG., PH.D., O. I. Butler, M.SC., and H. Sterling, B.SC.	'Applications of the 3 : 1 Pole-Changing Motor'	
J. C. Read, D.SC., and C. F. Gimson	'A High-Power Mechanical Contact Rectifier'	

GROUP C

The Blumlein–Browne–Willans Premium (value £20)

R. S. Webley, B.SC., H. G. Lubszynski, DR.ING., and J. A. Lodge, B.SC.	'Some Half-Tone Charge Storage Tubes'	

The Fahie Premium (value £10)

Capt. C. F. Booth, C.B.E., and B. N. MacLarty, O.B.E.	'The New High-Frequency Transmitting Station at Rugby'	

The Frank Gill Premium (value £10)

No award.

The Heaviside Premium (value £10)

I. A. Harris	'The Theory and Design of Coaxial Resistor Mounts for the Frequency Band 0–4 000 Mc/s'	

The Paris Exhibition (1881) Premium (value £10)

The late T. Lawrie, C.B.E., M.A.	'Highland Water Power—The Developments of the North of Scotland Hydro-Electric Board'	

The Webber Premium (value £10)

W. C. Bain, M.A., B.SC., PH.D.	'Possible Errors of a Particular Wide-Aperture Direction-Finder'	
	'The Theoretical Design of Direction-Finding Systems for High Frequencies'	

Oversea Premiums

For Senior Members (value £10)

D. B. Reay, M.SC.(ENG.)	'Distortion of Turbo-Alternator Rotor Windings through Thermal Stress'	

For Students and Graduates under 28 years of age (value £5)

No award.

GRADUATE AND STUDENT PREMIUMS

Premiums to the value of £10 each

Author	*Title*	*Section*
B. J. Chalmers and A. R. Daniels	'New Instruments for Induction Motor Analysis'	Bristol
G. A. Gibson	'Pulse Circuitry'	South Midland

Henry Nimmo Premium (value £10)

J. H. Denman	'Boiler House Fans'	Cardiff

Premiums to the value of £5 each

P. J. Bhatt, B.SC.(ENG.)	'Principles of Self-Regulation in Rotating Machines'	East Midland
C. F. R. Bradshaw, B.ENG.	'Arc Furnaces'	Sheffield
S. G. Griffiths	'Opportunities for the Engineer on Merseyside'	Mersey and North Wales
S. L. Hurst, B.SC.(ENG.)	'High Fidelity Sound Reproduction'	Bristol
B. James, B.E.	'Magnicon Power Amplifiers—General Theory and some Applications'	South-West Scotland
F. H. Steele, B.SC.(ENG.), and K. T. D. Hughes	'Television Outside-Broadcast Units'	London
R. J. Weir, B.ENG.	'The Design of a Low-Power X-Ray Set'	North-Eastern

Letters of Commendation

D. Mangnall	'The Metal Rectifier and its Importance to the Electrical Engineer'	North-Western
G. F. Stewart, B.SC.	'The Automatic Factory'	Sheffield
J. F. Winterbottom, B.SC.	'Properties and Applications of Some Recent Semi-Conductor Devices'	South Midland

THE INSTITUTE OF FUEL

Mr. J. R. Rylands, M.SC., M.I.MECH.E., MEMBER, has been elected President of The Institute of Fuel with effect from October, 1956. Mr. Rylands served as Chairman of the North Midland Centre of The Institution of Electrical Engineers in 1949, and he has also served on several Committees of the Council.

CONFERENCE ON STATIC ELECTRICITY IN TEXTILES

ZÜRICH: 13TH–17TH SEPTEMBER, 1956

The Textile Institute is holding a conference in Zürich from the 13th to 17th September, 1956, on Static Electricity in Textiles; the proceedings will be conducted mainly in English. Members who are interested in attending this conference should apply to the General Secretary, The Textile Institute, 10 Blackfriars Street, Manchester 3.

SCIENCE ABSTRACTS

The successful abstracting of the world's electrical literature depends on the co-operation of numerous specialist engineers willing to read and summarize articles on their own subjects, in foreign languages as well as English. The Editor of *Science Abstracts* appeals for more members to help in this work, for which fees are paid, and which will bring to them many articles they might not otherwise see. Abstractors are required in nearly all subjects, particularly Power Generation, Machines, Transformers, Switchgear, Electric Heating and Telephony; and in nearly all languages, particularly Czech, Dutch and Italian. Offers of assistance and inquiries should be addressed to The Editor, *Science Abstracts*, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

A CONVENTION ON CONTROL TECHNIQUE

HEIDELBERG: SEPTEMBER 1956

The Joint Group of the Verein Deutscher Ingenieure and the Verband Deutscher Elektrotechniker that is concerned with control technique is arranging a convention on this subject in Heidelberg University from the 25th to the 29th September, 1956. Members who are interested in this convention may obtain invitations to participate and further particulars from the Secretary of The Institution.

CO-OPERATIVE ELECTRICAL RESEARCH

The Electrical Research Association has recently published the first issue of a new journal intended to give general information about the research work in which its staff is engaged. The journal is called *Co-operative Electrical Research* and it will appear twice a year. In a Foreword to this issue, Mr. F. H. Bramwell, Chairman of the E.R.A. Council, writes:

It is proposed to include articles written by members of the staff and others closely associated with the work, reviewing on broad lines various aspects of the different sections of the E.R.A. activities and bringing out the effect of these on the practical problems facing the electrical and allied industries, whether manufacturers, suppliers or others.

These articles will be written so as to appeal to those in executive positions in the electrical and allied industries, who have a broad but not necessarily a specialized knowledge of the subjects and have neither the time nor the need to study them in great detail.

The Electrical Research Association has many facilities for giving advice and rendering services to its members; the *Journal* will provide the means of making the extent of these more widely known.

The issue contains a number of articles, including 'E.R.A. and the Electricity Supply Industry' by C. W. Marshall, 'Recent Research on Insulating Materials' by C. G. Garton, 'The Development of the Light Wood Pole Line and the E.R.A.' by H. W. Grimmitt, and 'Radio Interference' by W. Nethercot; a full obituary of Dr. S. Whitehead; and a note about the move to the new Leatherhead laboratories.

Co-operative Electrical Research is a readable periodical that will appeal to the electrical engineer who seeks information about the results of research in branches of electrical engineering in which he is not himself a specialist. Copies may be obtained from the E.R.A., Thorncroft Manor, Dorking Road, Leatherhead, Surrey, price 2s. 6d. each, plus 3d. postage.

British Nuclear Energy Conference: Forthcoming Programme

SEPTEMBER 25 *Tuesday*

A meeting sponsored by The Institution of Civil Engineers will be held in the building of that Institution, Great George Street, London, S.W.1, at 5.30 p.m. (tea at 5 p.m.). The following paper will be presented and discussed:

THE PROBLEM OF LIQUID AND GASEOUS EFFLUENT DISPOSAL AT WINDSCALE F. R. Farmer

NOVEMBER 22 *Thursday and* **23** *Friday*

A Symposium of papers on the Calder Works Nuclear Power Plant, which will be held at The Institution of Civil Engineers, Great George Street, London, S.W.1. Advance copies of the papers will be available at the beginning of November to members who wish to attend the meetings. The papers and discussions will be published in *The Journal of the British Nuclear Energy Conference*. A registration fee of £1 will be charged towards the cost of the advance copies. All those wishing to attend are requested to obtain an application form from the Secretary, British Nuclear Energy Conference, 1–7 Great George Street, London, S.W.1.

SESSION I *10 a.m. Thursday 22nd November*

INTRODUCTION AND GENERAL DESIGN

Chairman: Sir John Cockcroft, *Chairman of the Board*

CONFERENCE PROCEDURE Sir John Cockcroft

1 BRITISH NUCLEAR POWER PROGRAMME Sir Christopher Hinton

2 THE DESIGN STUDY R. V. Moore and B. L. Goodlet

3 THE CALDER WORKS PLANT R. V. Moore

DISCUSSION

Reporter: R. V. Moore

SESSION II *2 p.m. Thursday 22nd November*

TECHNICAL RESEARCH PROBLEMS

Chairman: Sir John Cockcroft

4 EXPERIMENTAL HEAT TRANSFER WORK P. Fortescue and W. B. Hall

5 EXPERIMENTAL PHYSICS P. Mummery

6 SHIELDING DESIGN W. Bonsall and C. Horton

7 BASIC DESIGN OF REACTOR G. Packman and B. Cutts

DISCUSSION

8 EARLY METALLURGICAL PROBLEMS L. M. Wyatt and R. A. U. Huddle

9 METALLURGICAL DEVELOPMENTS FOR CALDER WORKS L. Grainge and A. B. McIntosh

DISCUSSION

Reporters: J. Diamond and L. Rotherham

SESSION III *10 a.m. Friday 23rd November*

ENGINEERING DESIGN

Chairman: Mr. W. L. Owen

10 DESIGN AND CONSTRUCTION OF REACTOR VESSEL G. Brown, M. Noone and R. F. Bishop

11 URANIUM FUEL HANDLING K. Dent and G. W. Grossmith

12 DESIGN OF IMPORTANT PLANT ITEMS A. T. Bowden and G. H. Martin

DISCUSSION

13 STEAM CYCLE ANALYSIS W. R. Wootton

14 DESIGN AND CONSTRUCTION OF HEAT EXCHANGERS H. Morris and W. R. Wootton

DISCUSSION

Reporters: Sir Claude Gibb and R. E. Zoller

SESSION IV *2 p.m. Friday 23rd November*

LIGHT ENGINEERING AND ELECTRICAL

Chairman: Mr. J. Eccles

15 EQUIPMENT FOR CONTROL OF THE REACTOR J. H. Bowen and S. A. Ghalib

16 DETECTION OF FAULTY FUEL ELEMENTS E. Long, J. M. Laithwaite and K. W. Cunningham

17 REACTOR CONTROL AND INSTRUMENTATION R. J. Cox and K. R. Sandiford

18 SYSTEM CONTROL AND PROTECTION J. H. Bowen and E. Anderson

DISCUSSION

Reporter: D. Taylor

SESSION V *5.30 p.m. Friday 23rd November*

FUTURE DEVELOPMENTS AND SUMMARY

Chairman: Sir John Cockcroft

19 FUTURE DEVELOPMENTS OF GAS-COOLED REACTORS R. V. Moore

20 SUMMARY OF PROCEEDINGS Sir Christopher Hinton

LONDON

MEASUREMENT AND CONTROL SECTION

Bang-on Vaticination

The paper entitled *An On-Off Servo-Mechanism with Predicted Change-Over* was presented to the Section on the 14th February, 1956, by the authors, Mr. J. F. Coales and Mr. A. R. M. Noton.

The problem of optimum switching in a relay-controlled, or 'bang-bang', system was developed in the initial talk by Mr. Noton, who went on to describe the technique and experimental detail of their new on-off control system. A particular example of the system was exhibited and the live demonstration of its characteristics came as a fitting climax. The system performance was recorded by a pen recorder and the results handed round for all to inspect. A short review of the paper was published in last month's *Journal*.

The audience was composed mainly of specialists in the servo field and was a friendly gathering, with genuine interest in this new development. Almost everyone knew everybody else present.

Dr. A. M. Uttley opened the discussion and showed how the present system had emerged logically from the crude and earlier methods of change-over anticipation. He paid tribute to the ingenuity and subtlety of thought that had been required to produce this present system, and wondered whether the authors, in suggesting that it was valuable for high-power systems, were 'under-selling' their idea, the great point perhaps being that it is a better servo rather than that it saves money. Closing on a humorous note, Dr. Uttley referred to the first few sentences of the authors' first appendix, which reminded him of the famous man who wrote 'A little thought will convince the reader that . . .' to which someone replied that he had been unable to take sufficiently little thought to be convinced. The experience Dr. Uttley has had in predicting change-over time from maximum acceleration to maximum deceleration in motor-car driving made him intuitively uncertain as to the veracity of the results of this appendix.

Carrying on the humorous vein, Dr. J. C. West asked if the American terminology for this type of system quoted by the authors was based on the slang expression 'bang-on'. This speaker next discussed the value of linear prediction concepts for non-linear systems, and asked some detailed questions about the operation of the system given in the paper. Dr. J. P. Corbett and Dr. J. L. Douce added further technical contributions.

Mr. Coales then took his opportunity to reply to the speakers. Admirably answering the difficult questions, he went on to discuss the adaptability of the system for the self-determination of optimum performance for randomly varying inputs. He concluded by applauding the experimental work carried out by his younger colleague which had made this joint paper possible. Referring to himself as the father of this system, Mr. Coales started a simile which led the Chairman, Mr. W. Bamford, in his closing remarks to draw the logical conclusion that Mr. Noton must have been the gynaecologist.

J. C. W.

UTILIZATION SECTION

Order out of Chaos

At the meeting on the 19th April, 1956, were presented three related papers which, considered together, are an excellent example of the results of collaboration between university research and industry. A short review of these papers appears on p. 472.

The first was entitled *Temperature Rises in Electrical Machines as related to the Properties of Thermal Networks*, by J. J. Bates and Professor A. Tustin; it reviews the conditions under which an electrical machine can be regarded, for the purpose of relating temperature rises to losses, as a thermal network of lumped conductances and capacitances. The experimental results show that this relationship in a machine running at a given speed may differ considerably from the relationships for a thermal network, but for any given speed the equations are linear. The second paper was on *Temperature Rises in Electrical Machines on Variable Load and with Variable Speed* by the same two authors, who point out in it that in selecting an electrical machine one must estimate how hot the windings will become when the most onerous duty anticipated is performed, but this is difficult when the duty involves varying loads and speeds. They then go on to show how the mean temperature rise of a specified part, e.g. the armature winding, on a short-service run with variable load and speed will be related to the results of on-off tests on the test bed.

Performance and Heating Curves for Motors on Short-Run Duties, by Professor A. Tustin, D. F. Nettell and R. Solt, was the final paper read. This shows how curves may be prepared to facilitate the design or selection of motors for services with short runs, such as the operation of cranes or urban transport, and thereby provides a useful tool for such work.

In opening the discussion, Mr. C. C. Inglis suggested that a regular check ought to be taken of the temperature of motors, since rearrangements of these would often produce financial savings. It was the temperature of the motor that decided its life and this was of first importance economically.

A large number of others, both users and designers, took part in the discussion. One speaker, in referring to the single-phase system of electrification, on which British Railways were about to embark, felt that the new methods might make possible the use of higher temperatures and new insulating materials in the traction motors to be developed.

Some rather caustic remarks were made about design procedure, which was said to be too often based on intuition: much of the improvement in design to-day was really a reduction of the margins allowed in the past for the ignorance factor. The view was also expressed that the authors had brought 'order out of chaos', and their work might eventually lead to a procedure for designing the most efficient machine by feeding a specification into an electronic computer and obtaining the required design parameters as output.

A very relevant point made by one contributor was that, while efficiency is important, users of machines are more interested in commercial efficiency, and that one breakdown in a modern production plant may cost more than the price of several new motors.

R. H. R.

YORKSHIRE

NORTH MIDLAND CENTRE

Standard Tariffs

The seventh ordinary meeting of the Centre, which was held at York on the 10th April, 1956, was preceded in the afternoon by a most interesting visit to the new telephone exchange. Our thanks are due to Mr. T. Duerden for all the arrangements, and to Mr. G. E. T. Thomas of the Post Office Telephone Department for his kindness. In the evening, our Chairman, Mr. F. Barrell, welcomed the speaker, Mr. N. F. Marsh, and asked him to present a paper entitled *The Standardization of Retail Electricity Tariffs*, of which he is co-author with Mr. A. O. Johnson. We were charmed by Mr. Marsh's delivery of this most interesting paper, setting out as it does so clearly the circumstances which have led to the present degree of standardization. The discussion was led by Mr. W. K. Fleming, who referred to the useful work done in this field by the earlier committees of 1925 and 1929. The accent of the discussion was on the need for greater simplification. Our thanks to the speaker were voiced by the Chairman and these were enthusiastically supported.

Administration and Textiles

At the Annual General Meeting held at Leeds on the 1st May, 1956, under the chairmanship of Mr. F. Barrell, we re-elected Mr. A. R. Rumfitt and Mr. J. K. Swain as scrutineers, and after our Treasurer, Mr. J. V. Werrell, had submitted his report, Mr. G. Caton voiced our thanks to the retiring Auditors, Mr. J. J. Swarsbrick and Mr. J. D. Green, who were thereupon re-elected. We next had a very complete report from the Chairman of the year's activities, and welcomed two new Corporate Members. The appeal for the Benevolent Fund was then made by the retiring Treasurer, Mr. J. G. Craven, and the collection realized £11. In accordance with custom, the Annual General Meeting was followed by a lecture on a topic other than electrical engineering, and this year we invited Professor C. S. Whewell, Professor of Textile Technology, Leeds University, to give a lecture on *Man-Made Fibres*. Richly illustrated with slides and with many fabrics and fibres, this was a fascinating account of a subject which touches all our lives. The lecturer kept us all enthralled throughout his discourse, and was kind enough to answer questions, which came thick and fast; in the end, whilst there was still much that could have been said, the Chairman had to close the meeting by expressing our whole-hearted thanks to Professor Whewell for a most enjoyable evening.

Golf at Sandmoor

On the 8th May we held our annual golf competition at Sandmoor in aid of the Benevolent and Homes Fund. The weather was kind, and a good day's sport was enjoyed by our members and their friends. At a dinner in the club-house the same evening, our Chairman, Mr. F. Barrell, thanked Mr. J. Richardson, the Sandmoor captain, for his help, and paid tribute to the valuable work done, over the past years, by our retiring competition secretary, Mr. F. Smith. Our golf treasurer, Mr. H. S. Moody, thanked a long list of firms and individuals who had sent gifts for the auction. The Woodhouse Trophy was won by Mr. J. Hack, and other prize-winners were Messrs. R. B. Graham, W. A. Huffer, F. L. Parkin, Col. H. B. Somerville, and Messrs. L. F. Southorn and W. F. Wing. We are indebted for the assistance of Mr. E. Townsend, who acted as secretary of the competition in the absence of Mr. F. Smith. The Benevolent Fund will benefit by a sum which is likely to exceed that raised by previous efforts.

You're in the Army now

On the 15th May, 1956, we held a special meeting at Catterick, which was preceeded by a most interesting visit, in the afternoon, to the School of Signals, by kind permission of Lt.-Col. R. G. Miller. Here we were shown the methods and equipment which are used to train the officers and men of the Royal Signals Wing in the varied techniques of modern army communications work. We were all entertained to tea in the Helles mess, where later the evening meeting was held. At this meeting the convener, Lt.-Col. R. G. Miller, introduced Brig. Smijth-Windham, who welcomed us, saying that The Institution sprang from the Society of Telegraph Engineers, which had links with the Army of the Crimea. Our Chairman, Mr. F. Barrell, thanked the brigadier for staging the exhibition and for the use of the officers' mess for the reading of the paper. He then introduced Mr. H. Stanesby, Chairman of the Radio and Telecommunication Section, and invited him to give his Chairman's Address, entitled *A Review of Line and Radio-Relay Communication Systems*, which was delivered in London on the 19th October, 1955. This, we found, dealt with the relative merits of frequency-division multiplex and time-division multiplex, with radio links and radio-relay systems and the differing requirements of telephony and television for them, with the characteristics of klystrons, and with some aspects of tropospheric-scatter links. Mr. Stanesby urged that there should be agreement at international levels on bandwidth, preferably before national ones are fixed. A well-informed discussion followed, opened by Mr. C. A. Beer and supported by seven other speakers many of whom were signals officers. The vote of thanks to the author was moved by Brig. D. St. J. Hoysted, C.B.E., Chief Signal Officer, Northern Command.

Education Discussion Circle

This Circle has held three meetings during the session with an average attendance of eleven members, and it has been a very useful forum for the exchange of views. It is thought that its future activities may be reduced so that meetings are called only when there are matters of educational policy at issue. Our warmest thanks are due to Mr. W. Paterson, the convener of these meetings.

J. L.

NORTH MIDLAND UTILIZATION GROUP

At our fourth Group meeting at Leeds on the 21st February, 1956, the Chairman, Mr. J. C. W. Wilkinson, welcomed the speaker, Mr. L. Gosland, and called on him to present his paper entitled *Age and the Incidence of Fires in Electrical Installations*. The author explained that this paper was based on an E.R.A. report on this subject dealing with a survey of 1 100 fires in the three years 1951 to 1953. Our members found this paper most interesting and a lively discussion, opened by Mr. H. Moss and continued by five other members, covered many aspects of this subject. Our response to the vote of thanks must have shown the author our appreciation.

The fifth Group Meeting took the form of a discussion of the Wiring Regulations, and was reported in the June *Journal*, p. 345.

At the sixth Group meeting on the 17th April, our Chairman, Mr. J. C. W. Wilkinson, invited Mr. D. Edmundson

to present his paper entitled *Electrical and Magnetic Measurements in an Electrical Engineering Factory*. The lecture intrigued us with the ingenuity of the devices described. An interesting discussion, opened by Professor G. W. Carter and supported by six other members, rounded off the evening well, and we were in complete accord when our Chairman, in thanking the author, said that the experiment of bringing a Measurement Section paper of this type to a Utilization Group had been a complete success. J. L.

DISTRICT MEETINGS

Break . . .

The fourth District Meeting was held at Hull on the 1st March, 1956, when, with our convener, Mr. W. S. Milner, in the chair, we welcomed Mr. H. W. Wolff and Mr. T. G. F. Atherton to present for discussion their paper *Design, Performance and Application of Miniature Circuit-Breakers*, which was illustrated by many lantern slides and by practical demonstrations of switching transients. In reading the paper Mr. Wolff referred to the widespread use made of these miniature circuit-breakers in Europe and in the United States, and looked forward to a similar development in this country. Our thanks to the authors were expressed by Mr. Milner.

. . . and Make

At the fifth and last District Meeting at Hull on the 19th April, 1956, matters relating to District Meetings were discussed, together with a proposed visit to a power station in Yorkshire, before proceeding to the welcoming of the speakers, Mr. A. H. Pollard and Mr. N. Care, who presented their paper entitled *Automatic Circuit Reclosers*, of which they are co-authors with Mr. G. F. Pierson. Mr. Care stressed the importance of devices which would discriminate between transient and permanent faults in rural supplies, and claimed that this device, backed by slow-acting h.v. fuses, fulfilled these conditions. The interest in the paper, and the slides and film shown, was evidenced by the discussion, which was opened by Mr. H. Sheppard and continued by five other members. A vote of thanks to the speakers, coupled with the name of Mr. J. Harris, who had officiated with the slides and the film, was very ably proposed by Mr. C. Cameron-Kirby, at the invitation of our convener, Mr. W. S. Milner, who took the chair at this meeting. J. L.

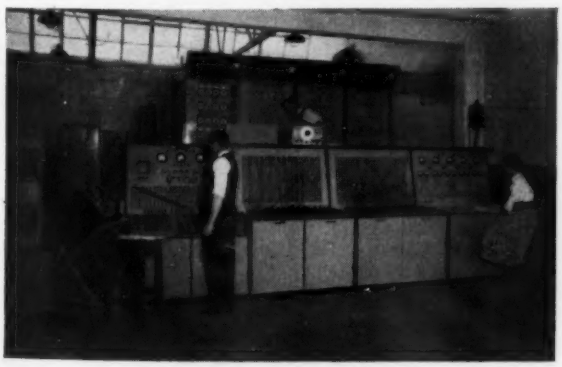
NEWS *from Abroad*

SOUTH AUSTRALIA

Computer Programme

For the first two meetings of its 1956 programme, the Oversea Committee for South Australia arranged two companion talks on analogue computers. The first, *An Introduction to Analogue Computers*, was given by Mr. J. P. Lonergan of the Weapons Research Establishment, Salisbury, South Australia, on the 13th April. He described how the basic operations of summation, integration, differentiation, multiplication and function generation are performed by a d.c. computer.

The Australian Guided Weapons Analogue Computer in use at the Weapons Research Establishment, Salisbury.



After dealing with ways and means of overcoming drift in d.c. amplifiers—a problem which held up progress on machines of this type for some time—the speaker showed how the various units of a computer must be interconnected to solve a typical simple problem, the solution of the differential equation describing the forced response of a damped oscillatory system.

The Australian Guided Weapons Analogue Computer, for which Mr. Lonergan was the Australian Department of Supply's design authority during its manufacture in England, is a general purpose d.c. machine. The lecturer described its principal features with the aid of slides, one of which is reproduced here, emphasizing its flexibility and its comprehensive test and calibration facilities. A number of small problems may be worked simultaneously and the character of a major problem can be changed completely in a surprisingly small time. For example, in less than a day a comprehensive missile-guidance problem has been replaced by an aerodynamic flutter problem in five degrees of freedom. Basic computing units incorporated in the machine include 100 drift-stabilized d.c. amplifiers, of which 21 may be used as integrators, and a variety of electronic function generators. External equipment such as curve followers and guided-weapon control systems may be included readily in the computation. In the design of these units emphasis was laid on accuracy of computation and repeatability. In a recent flutter problem, a long-term repeatability of better than $\frac{1}{2}\%$ was obtained in the determination of the zero damped condition for a wide range of operating conditions.

Mr. R. W. Hynes, who spoke at the second meeting on May 4th, presented the recent Institution paper on *Tridac*—

A Large Analogue Computing Machine, of which he is a co-author. Tridac is a computer installed at the Royal Aircraft Establishment, Farnborough. It has been designed specifically to solve the complex mathematical equations which describe the three-dimensional flight of a guided missile. The speaker was able with the help of a model missile mounted in gimbals, some slides and the previous introductory lecture, to bring a basic understanding of the intricacies of this £750000 monster within reach of all present. He pointed out that its immense cost was justified by the savings it afforded in test firings of actual missiles.

Both lectures drew excellent attendances and stimulated lively discussions. J. W. C.

OVERSEA ATTENDANCE REGISTER

During the period 1st June to 30th June, 1956, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

LE PAGE, W. C. (Lusaka, N. Rhodesia).
MACELWEE, Professor N. M., B.SC. (Christchurch, New Zealand).
PRATT, J. H. (Auckland).
ROBERTS, N. H., M.A., M.SC. (Geneva).
ROBINSON, D. H. (Port Sodas).
RUBERI, F. (Carácas, Venezuela).
STRICKLAND, A. M., B.SC.(ENG.) (Barakat, Sudan).
SUTTIE, G. F. (Christchurch, New Zealand).

Contents of the Current Issues of the *Proceedings*

DATE OF JOURNAL REVIEW OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (AUGUST 1956)

W. P. BAKER, B.SC.(ENG.)
August 1956 — **The Non-Destructive Testing of Electric Strength of Liquids** (PAPER NO. 2146 M)

B. C. ROBINSON, M.SC., PH.D.
April 1956 — **The Penetration of Surge Voltages through a Transformer Coupled to an Alternator** (PAPER NO. 1997 S, FEBRUARY 1956)

B. C. ROBINSON, M.SC., PH.D.
April 1956 — **The Propagation of Surge Voltages through Turbo-Alternators with Concentric-Conductor-Type Windings** (PAPER NO. 2018 S, FEBRUARY 1956)

J. S. H. GOODALL AND G. S. CHAPMAN
August 1956 — **An Electronic Over-Current Relay for Electrical Machines** (PAPER NO. 2109 U)

COLIN ADAMSON, M.SC.(ENG.), AND L. M. WEDEPOHL, B.SC.(ENG.)
Not yet reviewed — **Power System Protection with particular reference to the Application of Junction Transistors to Distance Relays** (PAPER NO. 2085 S)

J. W. T. WALSH, O.B.E., M.A., D.SC.
Not yet reviewed — **Lighting** (*A Review of Progress*) (PAPER NO. 2132)

C. D. J. STATHAM, B.ENG., PH.D.
June 1956 — **Underground Lighting in Coal Mines** (PAPER NO. 2034 U, MARCH 1956)

Discussion on **The Use of Electricity in the Production of Calcium Carbide** before the Western Utilization Group

E. L. E. WHEATCROFT, M.A., AND H. H. C. BARTON, B.A.
Special article to be published — **The Potentialities of Railway Electrification at the Standard Frequency** (PAPER NO. 1998 U, JANUARY 1956)

Written discussion on **Service Experience of the Effect of Corrosion on Steel-Cored Aluminium Overhead-Line Conductors**

Discussion on **Safety in the Use of Portable and Transportable Electrical Equipment in Industry** before the South Midland Centre, the North-Western Utilization Group, the North-Eastern Centre, the Sheffield Sub-Centre, the Southern Centre, the Mersey and North Wales Centre, the North Midland Utilization Group, the Western Utilization Group, and the Northern Ireland Centre

Discussion on **Short-Circuit Forces on Turbo-Alternator End-Windings** before the North-Western Supply Group and the Rugby Sub-Centre

Discussion on **Timing the Operation of Control Systems associated with Rotating Equipment** and **The Dynamic Braking of Induction Motors** before the South Midland Supply and Utilization Group

PART B. RADIO AND ELECTRONIC ENGINEERING (JULY 1956)

See *Journal*, July 1956, page 448.

PART C. MONOGRAPHS (MARCH 1956)

See *Journal*, March 1956, page 206.